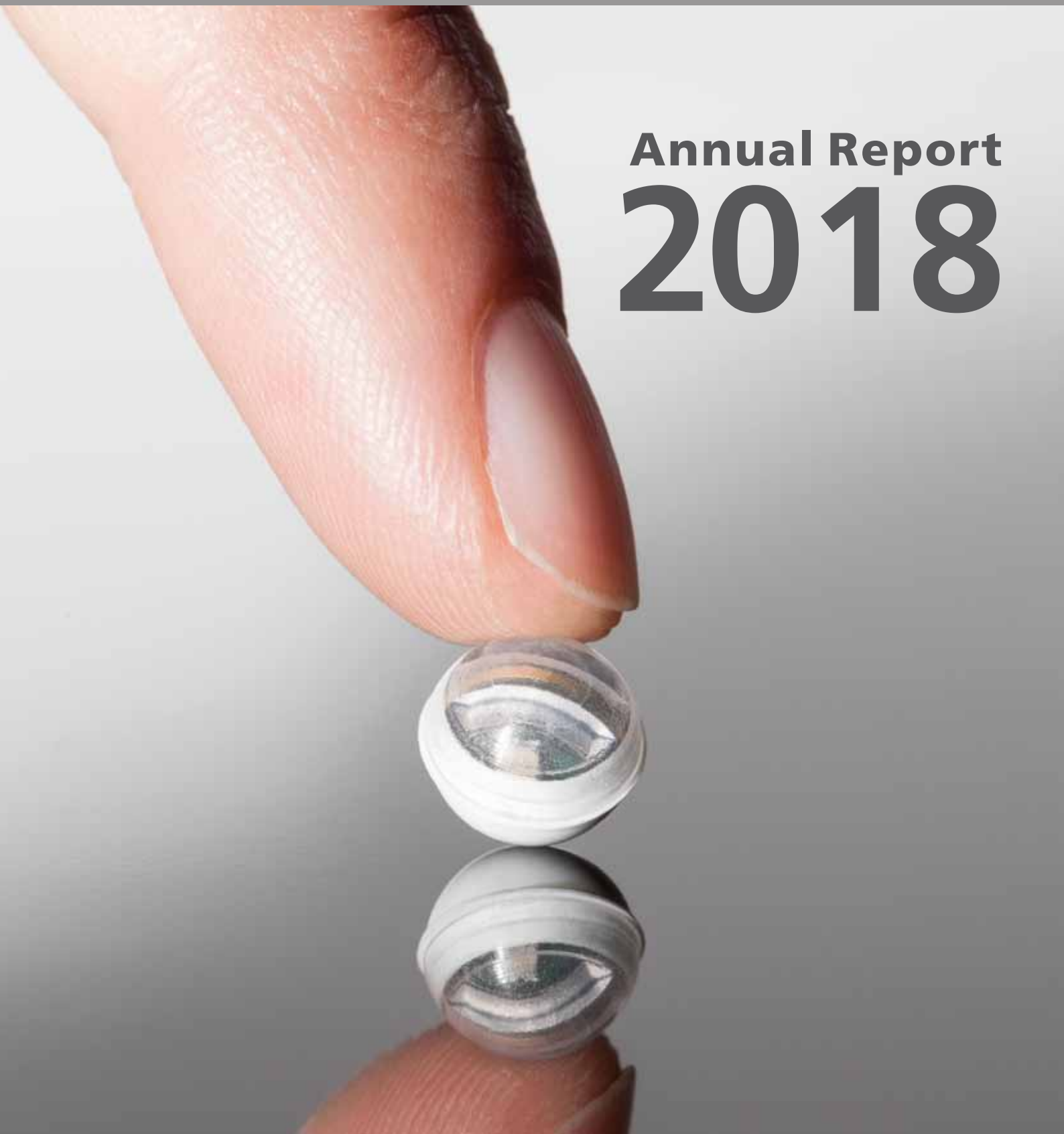
Fraunhofer
ENAS

FRAUNHOFER INSTITUTE FOR ELECTRONIC NANO SYSTEMS ENAS



Annual Report 2018

CONTENT

Cover page:
Miniaturized temperature probe with a diameter of 7.8 mm and wireless online transmitting capability from the process fluid developed in the idea contest »New products for the bioeconomy« funded by the BMBF.
Photo: Nora Heinisch / PLASMA Magazine
(by courtesy of our project partner Dr. Felix Lenk from the research group SmartLab systems at the Institute of Natural Materials Technology at TU Dresden)

PREFACE

Photo: Ines Escherich

»Don’t find fault, find a remedy!« (Henry Ford)

Dear friends and partners of the Fraunhofer Institute for Electronic Nano Systems, dear readers,

In 2018, we celebrated the 10th anniversary and the successful development of the Fraunhofer Institute for Electronic Nano Systems ENAS. We look back at a continuous positive development of our budget, and our performance is both acknowledged and appreciated. A large portion of our research volume is generated by contract-based research, i.e. in the framework of direct orders from industry and publicly funded projects. At this point, we would like to thank our partners and customers for their trust and support.

In order to also be a reliable partner in the future, we are working on the establishment of a quality management system. We are satisfied with the progress we have made in 2018 and we are looking forward to finalize the certification of the institute according to DIN EN ISO 9001:2015 in 2019.

Together with the institutes of the Fraunhofer Group for Microelectronics as well as the Leibniz Institutes IHP and FBI, we strengthen our cooperation and bundle our expertise in the Research Fab Microelectronics Germany.

We develop future topics further. Sensors and actuators for industry 4.0, harsh environment, agricultural applications and smart health are the focus. Moreover, we use nanotechnologies and new materials for novel components and systems.

In the annual report 2018, you find a selection of topics we have been working on during the past year. Let yourself be inspired.

Prof. Dr. Thomas Otto
Director (acting) of the Fraunhofer Institute for Electronic Nano Systems ENAS

photo: pixabay

STRATEGY PROCESS / FOLLOW-UP PROCESS

STRATEGY PROCESS / FOLLOW-UP PROCESS

Since its foundation in 2008, Fraunhofer ENAS can look back at a continuously positive development with high industrial revenues and a constant increase in budget and number of employees. Fraunhofer ENAS permanently monitors trends, developments and shifts in the markets to ensure and to expand its position in the market, to open new areas of application, to further-develop its R&D portfolio and to anticipate new markets. All this is subject of the continuous strategic process at Fraunhofer ENAS.

During the strategic process, we analyzed the project portfolio, goals, customers and markets intensely. The results are the base for our goals and action plans within a period of up to five years. The developed strategic goals and planned actions of the last strategic process were audited in 2016. Since then, Fraunhofer ENAS works in a follow-up process to fulfill the action plan. One of the major projects on which the institute's management decided on in 2017 addresses the certification of the entire institute in accordance with DIN EN ISO 9001:2015. The certification is planned for the 4th quarter of 2019. Furthermore, within the celebration of the 10th anniversary of our institute, the vision and mission of Fraunhofer ENAS was publicly presented.

Our quality policy

By implementing a quality management system, we want to ensure a systematic and continuous improvement of transparent and well-defined processes. In addition, we also support the realization of our strategic process in order to ensure a sustainable and secure future for our institute.

The satisfaction of our customers and the interest in the needs of other relevant stakeholders are our priority. Naturally, the management of Fraunhofer ENAS is committed to the Fraunhofer guiding principles and takes, as a role model, responsibility for the high quality of our research and development services.

According to the mission and vision of the Fraunhofer-Gesellschaft, we also stand for applied research, innovation for the benefit of the society and strengthening of the German and the European economy. Our institute leads strategic initiatives to meet future challenges, develops technological breakthroughs, shapes a balanced interaction between excellent research and application-oriented development, cooperates with companies and research organizations and uses synergetic effects. Guaranteed confidentiality, continuity in key positions, first-class equipment, reliable project management and professional handling of rights of use are the basis of our business activities and our understanding of quality.

With the implementation of the quality policy, we aim to fulfill the requirements of the standard DIN EN ISO 9001:2015 for the benefit of the institute and our customers:

- Measure and evaluate the success by predetermined and agreed parameters,
- Ensure a constant monitoring, review of efficiency and improvement of the quality management system,
- Promote our corporate and organizational culture,
- Adjustment of the business units as well as refining and further development of our areas of expertise,
- Actively contributing to the realization of the strategic levels of Fraunhofer-Gesellschaft.

Our vision

Fraunhofer ENAS is a top supplier and trendsetter for research and development services as well as prototyping and pilot production in the field of integrated smart systems. We work in the context of Fraunhofer-Gesellschaft.

Our mission

The Fraunhofer Institute for Electronic Nano Systems ENAS is the system and technology partner in the field of Smart Systems Integration by using Micro and Nano Technologies.

Our strength lies in the development of smart integrated systems for different applications. These systems combine electronic components with nano and micro sensors as well as actuators, communication units and self-sufficient power supply. Fraunhofer ENAS develops single components, processes and technologies for their manufacturing as well as system concepts and system integration technologies and helps to transfer them into production. The institute offers research and development services from the idea, via design and technology development or realization based on established technologies up to

On October 17, 2018, Fraunhofer ENAS celebrated its 10th anniversary with international guests. Greeting words were spoken by Prof. Dr. Reimund Neugebauer (President of the Fraunhofer-Gesellschaft), Michael Kretschmer (Prime Minister of the Free State of Saxony), Barbara Ludwig (Mayor of the City of Chemnitz) and Prof. Dr. Gerd Strohmeier (Rector of the Chemnitz University of Technology).
Photo: Ines Escherich

STRATEGY PROCESS / FOLLOW-UP PROCESS

tested prototypes. If standard components do not meet the requirements, Fraunhofer ENAS provides help in the realization of innovative and marketable solutions and thus, secures market shares.

We stand for:

- Customer orientation
- Quality
- Innovation for the benefit of customers and society
- Sustainability
- Scientific excellence

Strategic alliances

Research Fab Microelectronics Germany – One-Stop-Shop for the complete micro and nanoelectronics value chain

Fraunhofer ENAS is one of 13 members of the Research Fab Microelectronics Germany (FMD) – Europe's largest cross-location R&D collaboration for microelectronics and nanoelectronics, with over 2000 scientists.

www.forschungsfabrik-mikroelektronik.de

Within this new type of cooperation, the advantages of two strong and decentralized research organizations – the Fraunhofer-Gesellschaft and the Leibniz Association – are combined with the synergies of a central organization to form the world's most capable provider of applied research, development, and innovation within microelectronics and nanoelectronics. The close intermeshing and the uniform public face allow the FMD to serve not only customers from heavy industry, but also to offer SMEs and start-ups more comprehensive and simpler access to the next generation of technology.

The German Federal Ministry of Education and Research (BMBF) is funding the setup of the FMD to the tune of 350 million euros, largely in the modernization of the institutes' research equipment. With this funding, the BMBF intends to strengthen the innovativeness of the German and European semiconductor and electronics industry and is supporting the initiative with the largest investment in research devices since Germany was reunified.

A year and a half after the project started on April 6, 2017, a lot of new acquisitions for the modernization of the laboratory facilities at FMD's locations around Germany went into operation. The ceremonial opening of the first integration line was on September 28, 2018, as part of the 1st FMD Innovation Day at the Berlin-based Fraunhofer Institute for Reliability and Microintegration IZM, which hosted the event on behalf of all members.

At around the halfway point of the project, 45 percent of the planned investments for the FMD have been successfully fulfilled.

The setup of the Research Fab Microelectronics Germany is coordinated in a central business office in Berlin, although – true to the concept of a virtual organization – additional locations in Dresden and Munich have also been opened. The FMD business office is the central contact point for potential and existing customers and is thus a significant driver of the development of the business in the area of microelectronics and nanoelectronics.

In order to be able to offer nationally coordinated technology and system developments from a single provider, the technological expertise of the institutes was grouped into six overarching areas – the technology platforms known as Microwave and Terahertz / Power Electronics / Extended CMOS / Optoelectronic Systems / Sensor Systems / MEMS Actuators. Within these technology platforms, the FMD offers the market technological developments along the entire value creation chain, from system design to testing and reliability.

In addition to these technologically oriented offerings, the FMD also offers cross-institute application solutions from a single provider. This allows customers a way of realizing combined and optimized system solutions together with the FMD and its institutes. In doing so, the Research Fab works in synergy with the business units of all institutes involved. We, as the FMD, can thus offer our customers a wider range of application solutions.

In 2017, successful project involvements were set up and orders were completed in combination with the FMD. For 2018, projects based on the FMD investments with a volume of 41.1 million euros can already be identified, which represents a significant success at such an early stage. The industrial share of this project volume is already at 30 percent, which highlights the importance of this unique cooperation in German microelectronics research to industry.

In 2019, the Research Fab Microelectronics Germany will enter the next phase. After establishment and structuring of the organization, the largest cross-location R&D collaboration for microelectronics and nanoelectronics in Europe, in partnership with its institutes, will prove its mettle on the market.

Full steam ahead – at the opening ceremony of the first FMD integration line. From left to right: Prof. Matthias Kleiner, President of the Leibniz Association; Prof. Georg Rosenfeld, former member of the board of the Fraunhofer-Gesellschaft; Prof. Hubert Lakner, Chairman of the Steering Committee of the Research Fab Microelectronics Germany; and Dr. Michael Meister, parliamentary undersecretary at the Federal Ministry of Education and Research (BMBF).
Photo: Research Fab Microelectronics Germany

STRATEGY PROCESS / FOLLOW-UP PROCESS

USeP – Universal Sensor Technology Platform for IoT Systems of the Next Generation

www.enas.fraunhofer.de/usep

Fraunhofer ENAS, GLOBALFOUNDRIES Dresden as well as the Fraunhofer Institutes IPMS, IZM and IIS/EAS jointly work on the research project USeP (Universal Sensor Technology Platform), which focusses on the development of a new type of sensor technology platform. This platform enables the automatic generation of a wide range of innovative components and their integration into a complete system in a modular concept. The project partners focus on a central control and processing unit with numerous interfaces and a wide selection of conventional and prospective sensors and actuators. Beside a system architecture with flexible building blocks, the platform offers innovative solutions for hardware and IT security. Overall, the sensor module with its diverse design versions shall cover hundreds of application scenarios. The project is funded by the Free State of Saxony and the European Union as part of the European Regional Development Fund (ERDF).

Sensry GmbH was founded in November 2018 for the marketing of the sensor platform. Sensry started operations with the goal of developing and commercializing a universal sensor platform for the development of electronic components, modules and systems.

The basis for the technology platform, which particularly benefits SMEs, is the 22FDX technology (Fully Depleted SOI) by GLOBALFOUNDRIES. Fabricated in Dresden, it enables highly integrated chips with energy-efficient and inexpensive properties. The participating Fraunhofer Institutes contribute their competences and expertise in the fields of innovative packaging, concept development, system design, sensor technology, data transmission as well as simulation and testing. In addition, the project USeP ensures that the results are applicable to next generations of technologies and that companies are able to use the new sensor technology platform for as long as possible.

Smart Systems Hub – Enabling IoT

www.smart-systems-hub.de

Fraunhofer ENAS actively engages in the development of the Smart Systems Hub – Enabling IoT, which aims at building a close network of Saxon experts in the key areas hardware – software – connectivity. In 2018, the Smart Systems HUB GmbH was founded and its managing director was appointed, thus, passing the responsibility for the further development to the company. Its three shareholders, Silicon Saxony e.V., HighTech Startbahn and 5G Lab GmbH as well as its key partners GLOBALFOUNDRIES Dresden, Infineon Technologies, SAP and T-Systems Multimedia Solutions support the Smart Systems HUB.

Fraunhofer ENAS engages in both, public events of the Smart Systems Hub and in the trails »Smart Maintenance« and »Smart Sensor and Production Systems for Industrial IoT«. The latter trail aims at presenting innovative solutions for a full digitization of production along the entire value chain. In particular, various aspects of IoT are a focal point, for instance sensor-based provision of device data, their analysis and interpretation as well as feedback of supporting and production relevant information. Additionally, with visualizing and displaying the devices in Augmented Reality, this trail displays scenes of a full digitization process.

The 2nd Smart Systems Hub Meet-up was hold at SAP in Dresden on February 26, 2018. and the attendees discussed about the joint project of GLOBALFOUNDRIES and Fraunhofer »Universal Sensor Platform USeP«. Photo: Susann Hering, Silicon Saxony e.V.

photo: Fraunhofer

FRAUNHOFER ENAS: PROFILE

FRAUNHOFER-GESELLSCHAFT

www.fraunhofer.de

Research of practical utility lies at the heart of all activities pursued by the Fraunhofer-Gesellschaft. Founded in 1949, the research organization undertakes applied research that drives economic development and serves the wider benefit of society. Its services are solicited by customers and contractual partners in industry, the service sector and public administration.

At present, the Fraunhofer-Gesellschaft maintains 72 institutes and research units. The majority of the more than 26,600 staff are qualified scientists and engineers who work with an annual research budget of 2.6 billion euros. Of this sum, 2.2 billion euros is generated through contract research. Around 70 percent of the Fraunhofer-Gesellschaft's contract research revenue is derived from contracts with industry and from publicly financed research projects. Around 30 percent is contributed by the German federal and state governments in the form of base funding, enabling the institutes to work ahead on solutions to problems that will not become acutely relevant to industry and society until five or ten years from now.

International collaborations with excellent research partners and innovative companies around the world ensure direct access to regions of the greatest importance to present and future scientific progress and economic development.

With its clearly defined mission of application-oriented research and its focus on key technologies of relevance to the future, the Fraunhofer-Gesellschaft plays a prominent role in the German and European innovation process. Applied research has a knock-on effect that extends beyond the direct benefits perceived by the customer: Through their research and development work, the Fraunhofer Institutes help to reinforce the competitive strength of the economy in their local region, and throughout Germany and Europe. They do so by promoting innovation, strengthening the technological base, improving the acceptance of new technologies, and helping to train the urgently needed future generation of scientists and engineers.

As an employer, the Fraunhofer-Gesellschaft offers its staff the opportunity to develop the professional and personal skills that will allow them to take up positions of responsibility within their institute, at universities, in industry and in society. Students who choose to work on projects at the Fraunhofer Institutes have excellent prospects of starting and developing a career in industry by virtue of the practical training and experience they have acquired.

The Fraunhofer-Gesellschaft is a recognized non-profit organization that takes its name from Joseph von Fraunhofer (1787–1826), the illustrious Munich researcher, inventor and entrepreneur.

Figures from January 2019

FRAUNHOFER ENAS

www.enas.fraunhofer.de

The Fraunhofer Institute for Electronic Nano Systems ENAS is the specialist and development partner in the field of Smart Systems and their integration for various applications. The challenge of combining micro and nano sensors as well as actuators, communication units and self-sufficient power supply to build Smart Systems is the main focus of Fraunhofer ENAS and hence, the base for the internet of things. Application areas of our R&D services are i.a. semiconductor industry (equipment and material manufacturer), aeronautics, automotive industry, communication technology, the security sector, logistics, agriculture, process technology and medical as well as mechanical engineering.

Fraunhofer ENAS develops single components, manufacturing technologies and system concepts, system integration technologies and actively supports the technology transfer for and with its customers.

Whether Start-up, SME or large enterprise, Fraunhofer ENAS offers innovation consulting and supports customer projects, starting from the idea, via design and technology development or realization based on established technologies up to tested prototypes. If standard components do not meet the requirements, Fraunhofer ENAS provides expert assistance in the realization of innovative and marketable products

In order to focus its activities and to ensure a long-term scientific and economic success, Fraunhofer ENAS puts special emphasis on the five business units:

- Micro and Nanoelectronics
- Sensor and Actuator Systems
- Technologies and Systems for Smart Power and Mobility
- Technologies and Systems for Smart Health
- Technologies and Systems for Smart Production

The business units address different markets, different customers and different stages of the value chain depending on the required research and development services.

From an organizational point of view Fraunhofer ENAS is subdivided into the departments Advanced System Engineering, Back-End of Line, Micro Materials Center, Multi Device Integration, Printed Functionalities, System Packaging, and Administration. The headquarters of Fraunhofer ENAS are located in Chemnitz. The department Advanced System Engineering is seated in Paderborn. In addition, a project group of the department Micro Materials Center is working in Berlin-Adlershof.

ORGANIZATIONAL STRUCTURE

Fraunhofer Institute for Electronic Nano Systems ENAS

Director (acting): Prof. Dr. Thomas Otto
Deputy director: Prof. Dr. Stefan E. Schulz

Department
Multi Device Integration
Acting: Dr. S. Kurth / Dr. A. Weiß

Department
Micro Materials Center
Prof. Dr. Sven Rzepka

Department
Printed Functionalities
Dr. Ralf Zichner

Department
Back-End of Line
Prof. Dr. Stefan E. Schulz

Department
System Packaging
Dr. Maik Wiemer

Department
Advanced System Engineering
Dr. Christian Hedayat

Administration
Head: Dr. Tina Kießling
Technical head: Uwe Breng

Marketing / Public Relations
Advisor to Institute Management
Dr. Martina Vogel

Business Unit
Micro and Nanoelectronics
Prof. Dr. Stefan E. Schulz

Business Unit
Sensor and Actuator Systems
Prof. Dr. Karla Hiller

Business Unit
Technologies and Systems for
Smart Power and Mobility
Dr. Steffen Kurth

Business Unit
Technologies and Systems for
Smart Health
Dr. Mario Baum

Business Unit
Technologies and Systems for
Smart Production
Dr. Ralf Zichner

International Offices

Fraunhofer Project Center
at Tohoku University, Japan
Prof. Dr. Motoko Kotani
Prof. Thomas Otto
Assoc. Prof. Dr. Joerg Froemel
Dr. Maik Wiemer

Office Shanghai, China
SHI Min

Office Manaus, Brazil
Hernan Valenzuela

Chemnitz University of Technology

Center for Microtechnologies (ZfM)
Faculty of Electrical Engineering and Information Technology

President: Prof. Dr. Thomas Otto
Deputy director: Prof. Dr. Karla Hiller

Department
Lithography and Pattern Transfer
Dr. Danny Reuter

Department
Layer Deposition
Dr. Sven Zimmermann

Professorship of
Microtechnology
Prof. Dr. Thomas Otto

Honorary Professor of
Opto Electronic Systems
Prof. Dr. Thomas Otto

Honorary Professor of
Nanoelectronics Technologies
Prof. Dr. Stefan E. Schulz

Honorary Professor of
Reliability of Smart Systems
Prof. Dr. Sven Rzepka

Faculty of Mechanical Engineering

Professorship of Digital Printing
and Imaging Technology
Prof. Dr. Reinhard R. Baumann

Clusters of Excellence

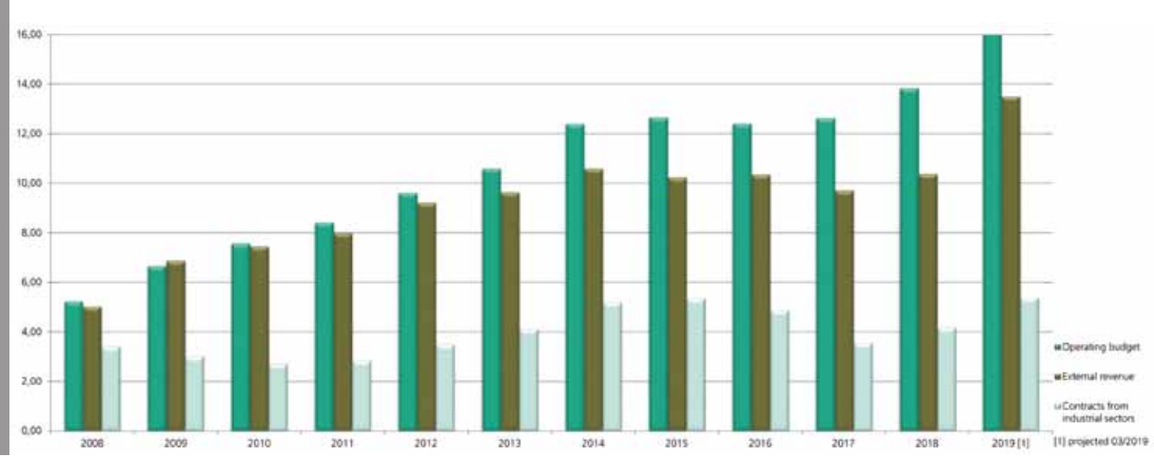
MERGE
Prof. Dr. Thomas Otto
Martin Schüller

cfaed
Prof. Dr. Stefan E. Schulz
Dr. Sascha Hermann

Paderborn University

Professorship of Sensor Technology
Prof. Dr. Ulrich Hilleringmann

FACTS AND FIGURES



Development of the Fraunhofer ENAS

	Year										
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Operating budget (in million euros)	5.2	6.7	7.6	8.4	9.6	10.6	12.4	12.65	12.41	12.62	13.83
Increase of the budget (in relation to 2008)	–	29 %	46 %	62 %	85 %	104 %	138 %	143 %	139 %	143 %	166 %
Industrial revenues (in million euros)	3.4	3	2.8	2.8	3.49	4.1	5.2	5.24	4.85	3.54	4.18
Investment (in million euros)	0.65	5.45	6.8	1.5	1.81	1.44	7.23	2.02	1.89	2.72	1.7
Staff	63	73	91	102	104	125	129	127	132	139	157
Apprentices	0	2	3	5	6	7	7	6	7	6	8
Students and student assistants	10	10	20	40	43	51	51	43	43	35	50
Publications and oral presentations	61	75	114	119	112	215	198	173	176	144	141
Patents	7	5	13	20	8	17	9	9	12	6	9
Doctoral Thesis	6	0	4	2	3	3	3	5	3	5	2

Financial situation and investment

The year 2018 was characterized by a rapid growth of the budget of the Fraunhofer ENAS by 9.6 percent. The institute generated external revenues of 10.36 million euros. The revenue quota is 74.9 percent. Both numbers reflect the main focus of Fraunhofer ENAS on further technological development of the institute within Fraunhofer internal programs. Orders from German and international industrial companies amount to 4.18 million euros, which represents an increase of 18 percent. The operational budget of Fraunhofer ENAS increased by 1.2 million euros to 13.83 million euros in 2018.

The investments of the year 2018 were 1.70 million euros. Altogether, the total budget amounted to 15.53 million euros.

Head of administration:
Dr. Tina Kießling
Phone: +49 371 45001-210
E-mail: tina.kiessling@enas.fraunhofer.de

Personnel development

At the end of the year 2018, Fraunhofer ENAS employed 157 people in Chemnitz, Paderborn and Berlin. Twelve employees were hired, whereas five employees left the institute.

On December 31, eight apprentices in total worked and learned at Fraunhofer ENAS. Furthermore, two apprentices successfully completed their training in summer 2018. In cooperation with Chemnitz University of Technology and Paderborn University, students and young scientists have successfully defended their graduate theses.

At the end of 2018, Fraunhofer ENAS employed 50 interns, graduate students/master's students and student aids. This employee base continues to prove itself as an excellent source for young scientists and technicians.

BOARD OF TRUSTEES

The board of trustees is an external advisory body attached to the institute. It consists of representatives fom science, industry, business, and public life. The members of the board of trustees are appointed by the Executive Board of Fraunhofer-Gesellschaft with the approval of the director of the institute. Their annual meetings are attended by at least one member of the Executive Board of the Fraunhofer-Gesellschaft.

In 2018, the members of the Fraunhofer ENAS board of trustees were:

Chairman:
Prof. Dr. Udo Bechtloff, Prof. Bechtloff Unternehmensberatung

Deputy chairman:
Prof. Dr. Hans-Jörg Fecht, Director, Institute of Micro and Nanomaterials, Ulm University

Members of the board of trustees:
MRn Dr. Annerose Beck, Head of Unit, Saxon State Ministry of Higher Education, Research and the Art
Jürgen Berger, Division Director Electronic and Micro Systems, VDI/VDE Innovation + Technik GmbH
Dr. Wolfgang Buchholtz, Manager Project Coordination, GLOBALFOUNDRIES Dresden
Dr. Stefan Finkbeiner, CEO, Bosch Sensortec GmbH
Prof. Dr. Maximilian Fleischer, Corporate Technology, Siemens AG
Dr. Arbogast M. Grunau, Senior Vice President Corporate R&D, Schaeffler Technologies AG & Co. KG
Dr. Christiane Le Tiec, CTO Ozone Products, MKS Instruments Deutschland GmbH
MDirigin Barbara Meyer, Head of Department, Saxon State Ministry of Economy, Technology and Transportation
MR Hermann Riehl, Head of Unit, German Federal Ministry of Education and Research (BMBF)
Thomas Schmidt, State Minister, Saxon State Ministry for the Environment and Agriculture
Prof. Dr. Ulrich Schubert, Director, Jena Center for Soft Matter, Jena University
Dr. Ina Sebastian, Senior Director R&D&I Policy, Infineon Technologies AG
Uwe Schwarz, Manager Development MEMS Technologies, X-FAB MEMS Foundry GmbH
Prof. Dr. Gerd Strohmeier, Rector, Chemnitz University of Technology

At the end of the year 2018, MR Hermann Riehl left our board of trustees. We are grateful for his participation and support. We welcome Dr. Ina Sebastian from Infineon Technologies AG as new member of the board.

We thank all board members and especially the chairman Prof. Udo Bechtloff and the deputy chairman Prof. Hans-Jörg Fecht for supporting our institute.

FRAUNHOFER ENAS – PARTNER FOR INNOVATION

As an innovative partner for our customers, Fraunhofer ENAS develops single components, processes and technologies for their manufacturing as well as system concepts and system integration technologies and helps to transfer them into production. The institute offers a research and development service portfolio, starting from the idea, via design and technology development or realization based on established technologies up to tested prototypes. If standard components do not meet the requirements, Fraunhofer ENAS assists in the realization of innovative and marketable solutions.

Interdisciplinary cooperation – key to success

Fraunhofer ENAS is an active member of different worldwide, European and regional industry-driven networks, starting from Semi and the Micromachine Center, via EPoSS – the European Technology Platform on Smart Systems Integration, Silicon Saxony and IVAM up to the Smart Systems Campus Chemnitz. The complete list is included in the attachment.

Cooperation with the Smart Systems Campus

Fraunhofer ENAS is located on the Technology Campus Reichenhainer Straße, more specifically on the Smart Systems Campus Chemnitz. The Smart Systems Campus is an innovative network with expertise in micro and nanotechnologies as well as in smart systems integration. The campus connects basic (Chemnitz University of Technology in particular) and applied research with the entrepreneurial spirit of young, newly founded businesses based in the start-up building and with companies that are already fully established in the market. The Smart Systems Campus is part of the ever-expanding »Technologiecampus Süd« in the city of Chemnitz. For instance, in late 2017, the campus was connected to the tram network and the scientific building MAIN was completed in 2018.

RESEARCH AND DEVELOPMENT SERVICE PORTFOLIO

- Development, design, packaging and test of MEMS/NEMS
- Methods and technologies for wafer to wafer and chip to wafer bonding
- Integration of nano functionalities, e.g. CNTs, quantum dots, spintronics, memristors
- Metallization: interconnect systems for micro and nanoelectronics and 3D integration
- Beyond CMOS technologies
- Simulation and modeling of devices, processes and equipment for micro and nano systems
- Material and reliability research
- Analytics for materials, processes, components and systems
- High-precision sensors and actuators
- Development of printed functionalities for electronic applications
- Application-specific wireless data and energy systems
- Development of microfluidic systems and biosensor integration
- Sensor and actuator systems with control units, integrated electronics, embedded software and user interface
- Reliability of components and systems

MARKETS AND FIELDS OF APPLICATION

- Semiconductor, semiconductor equipment and materials manufacturer
- Communication technology
- Medical engineering and life sciences
- Agriculture
- Mechanical engineering
- Process engineering
- Security
- Automotive industry
- Logistics
- Aerospace
- Internet of Things

During a festive ceremony on December 17, 2018, the continuative contract between Tohoku University Sendai, one of the Excellence Universities in Japan, and Fraunhofer-Gesellschaft for the continuation of the Fraunhofer ENAS Project Center »NEMS/MEMS devices and manufacturing technologies at Tohoku University« was signed. Photo: Tohoku University

Photo: Dirk Hanus

Cooperation with industry

Within the working field of smart systems integration, Fraunhofer ENAS strongly supports the research and development of many small and medium-sized companies as well as large-scale industry. By integrating smart systems in various applications, Fraunhofer ENAS addresses the branches and markets mentioned in the green box on page 21.

The most common way of cooperating with industrial partners is contract research. However, if the tasks and challenges are too complex, we offer pre-competitive research. In those cases, teaming up with companies and research institutes, while using public funding support, is more effective than operating alone.

In 2018, Fraunhofer ENAS has cooperated and collaborated with more than 150 partners from companies worldwide.

Transfer of research and development results and technologies into industrial applications
Based on the application-oriented focus of research, Fraunhofer ENAS is able to support innovations developed together with small and medium-sized companies as well as large-scale, internationally established companies. For instance, Fraunhofer ENAS transferred technological expertise to partners in Germany, Europe and Asia in order to enable them to build their own fabrication capabilities. Furthermore, there is a strong cooperation with MEMS foundries to transfer MEMS designs, developed at Fraunhofer ENAS, into a commercial fabrication technology. Hereby, we especially support SMEs in getting access to innovative sensor solutions.

Cooperation with universities and research institutes

Fraunhofer ENAS has established a strategic network with research institutes and universities in Germany and worldwide. Long-term partnership exists with the Tohoku University in Sendai, the Fudan University Shanghai and the Shanghai Jiao Tong University. Fraunhofer ENAS and the Tohoku University have been cooperating in the field of new materials for microelectronic systems for many years. Therefore, the Fraunhofer Project Center »NEMS / MEMS Devices and Manufacturing Technologies at Tohoku University« was established in 2012. Nowadays, the project center is not only a platform for joint research and development activities but also a common platform for offering R&D services to industry. To further perpetuate and intensify the joint research, a new agreement for continuing the cooperation was signed in December 2018.

www.enas.fraunhofer.de/fraunhofer-project-center

Moreover, Fraunhofer ENAS works closely with the local universities, in particular with Chemnitz University of Technology and Paderborn University. The cooperation ensures synergies between the basic research conducted at the universities and the more application-oriented research at Fraunhofer ENAS. The main cooperation partner at Chemnitz University of Technology is the Center for Microtechnologies at the Faculty of Electrical Engineering and Information Technology. The cooperation includes not only common research projects but also a joint use of equipment, facilities and infrastructure. Printed functionalities and lightweight structures are topics of the cooperation with the Faculty of Mechanical Engineering. In August 2018, the new building of the »Center for Materials, Architectures and Integration of Nanomembranes« (MAIN) was ceremonially handed over to Chemnitz University of Technology by the Saxon minister of state for science and arts, Dr. Eva-Maria Stange and the Saxon minister of state for finance, Mr. Matthias Haß. Already existing activities between the Faculty of Electrical Engineering and Information Technology, the Faculty of Natural Sciences and their research partners are now united under one roof. Fraunhofer ENAS collaborates with the research center MAIN in the field of nanomembrane-based materials, one of the most modern research areas of materials engineering and sciences. The department Advanced System Engineering, located in Paderborn, continues the close cooperation with the Paderborn University especially in the field of electromagnetic reliability and compatibility, wireless energy and data transmission technology and wireless sensors nodes for mechanical engineering.

www.zfm.tu-chemnitz.de

www.uni-paderborn.de

Multiple Excellency – cooperation within clusters of excellence

By the end of 2018, Fraunhofer ENAS and the Center for Microtechnologies of Chemnitz University of Technology worked in two clusters of excellence funded by the Federal Ministry of Education and Research (BMBF).

MERGE – Technologies for Multifunctional Lightweight Structures
The Cluster of Excellence MERGE »Technologies for Multifunctional Lightweight Structures« based at Chemnitz University of Technology was coordinated by Prof. Kroll, Director of the Institute of Lightweight Structures at the Faculty of Mechanical Engineering. The main object of the cluster was the fusion of basic technologies suitable for mass-production, comprising plastic, metal, textile and smart systems for the development of resource-efficient products and production processes. More than 100 researchers and technicians worked in the six domains of the cluster. Fraunhofer ENAS played a significant role in research area D, called Micro and Nano Systems Integration.

www.tu-chemnitz.de/MERGE

FRAUNHOFER ENAS – PARTNER FÜR INNOVATIONEN

Center for Advancing Electronics Dresden cfaed

»The Center for Advancing Electronics Dresden cfaed« focused on the development of promising technologies for micro and nanoelectronics. The cluster of excellence aimed at complementing and expanding todays leading CMOS technology by adding novel technologies, thus developing future electronic information processing systems. Prof. Fettweis was the head of the cluster, which was based at TU Dresden. Research teams from eleven institutions were cooperating interdisciplinary in nine different research paths. Scientists of Fraunhofer ENAS and the Center for Microtechnologies of Chemnitz University of Technology jointly worked on the carbon path and the biomolecular assembled circuit (BAC) path. Within the carbon path, CNT FETs have been developed and prototyped using a wafer level technology. The application focused on analog high-frequency circuits. Within the BAC path, Chemnitz' scientists worked on structuring on wafer level, which is necessary for the self-assembly of deoxyribonucleic acid (DNA).

www.tu-dresden.de/cfaed

Cooperation within Fraunhofer-Gesellschaft

Since its formation, Fraunhofer ENAS is part of the Fraunhofer Group for Microelectronics. Moreover, Fraunhofer ENAS is a member of the Fraunhofer Nanotechnology Alliance, the Fraunhofer Automobile Production Alliance and the Fraunhofer Technical Textiles Alliance. Dependent on the topic, Fraunhofer ENAS also participates in the Fraunhofer Clusters 3D Integration and Nanoanalytics.

Together with the other institutes of the Fraunhofer Group for Microelectronics, Fraunhofer ENAS is part of the Research Fab Microelectronics Germany (see page 8) and participates in the Heterogeneous Technology Alliance. This alliance links the Fraunhofer Group for Microelectronics with the European research partners CEA-Leti, CSEM and VTT. Together they offer the development of microtechnologies, nanoelectronics and smart systems for next-generation products and solutions.

Fraunhofer-Gesellschaft is tackling the current challenges facing German industry by putting a strategic focus on its lighthouse projects. These projects aim at exploiting the potential for synergies within Fraunhofer-Gesellschaft by bringing different Fraunhofer Institutes and their respective expertise together. Fraunhofer ENAS manages and coordinates the lighthouse project »Go Beyond 4.0«, which was launched in December 2016. Within the lighthouse project »Theranostic Implants«, Fraunhofer ENAS is working together with eleven other Fraunhofer Institutes on smart implants. The third lighthouse project Fraunhofer ENAS is involved in »eHarsh«, focusses on developing and providing a technology platform for sensor systems that can be applied in extremely harsh environments.

High-Performance Centers combine and link the competences of research institutes and universities within a certain region. Fraunhofer ENAS is working in two High-Performance Centers. The High-Performance Center »Smart Production« started in September 2017. The High-Performance Center »Functional Integration of Micro and Nanoelectronics« started its work in 2016 and was positively evaluated in 2017.

Lighthouse projects

Go Beyond 4.0

The demand for innovative and individualized devices for the future markets automotive, aerospace, photonics and manufacturing is growing in general. The highly qualified functionalities of the respective devices are realized by using modern functional materials. The lighthouse project »Go Beyond 4.0« addresses mass production of future products down to batch size 1 by integrating digital manufacturing processes, such as inkjet printing as an additive process and laser processing as an ablative process, into existing mass manufacturing environments. In order to achieve this goal, Fraunhofer Institutes ENAS, IWU, IFAM, ILT, IOF and ISC interdisciplinary combine their expertise in the fields of mechanical engineering, electrical engineering, photonics and material science. Following the concept, a reliable zero error production will systematically be integrated into the process chain to manufacture product demonstrators. The demonstrators address the major markets automotive, aerospace and lighting: smart door, smart wing and smart luminaire. To realize the demonstrators, the digital production technologies (digital printing and laser processing) will be adapted to the geometries of the individual demonstrators and the material properties.

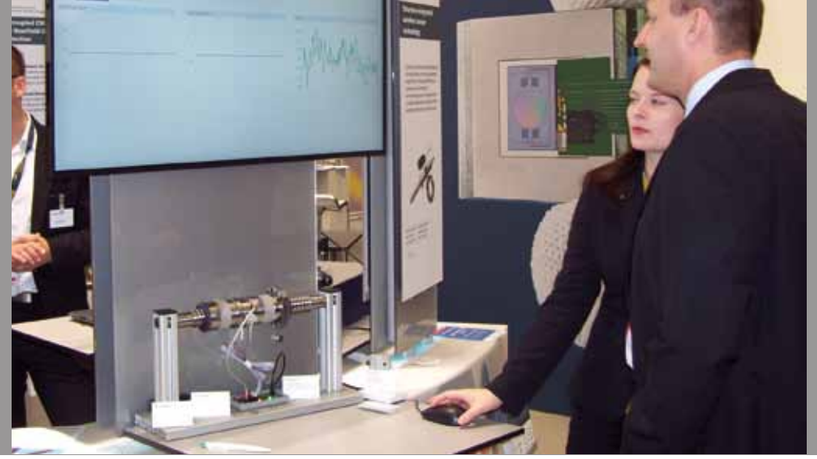
www.go-beyond-four-point-zero.de

Theranostic Implants

Theranostic implants are complex implantable medical products, which combine both diagnostic and therapeutical features in one system. The requirements for implants of the next generation are enormous: highly complex with small dimensions and low weight, stable functionality within the body (a warm and moist environment) and surrounded by constant cell growth. Crucial factors are the power supply and biocompatibility with the body. The project consortium focuses on a technology platform for power and signal solutions as well as longevity and compatibility of the implants in particular. The permanent monitoring of vital parameters helps in purposefully deploying therapeutic measures. Within the Fraunhofer lighthouse

www.enas.fraunhofer.de/theranostic-implants

FRAUNHOFER ENAS – PARTNER FÜR INNOVATIONEN



The High-Performance Center »Functional Integration of Micro and Nanoelectronics« introduced the joint project »Structure-integrated wireless sensor technology for manufacturing systems (SdSeMa)« at international exhibitions – here at the SENSOR+TEST in Nuremberg, Germany.
Photo: Fraunhofer-Gesellschaft

project, twelve Fraunhofer Institutes (management: Fraunhofer IBMT) worked cooperatively on three subprojects, which focused on skeletal, cardiovascular and neuromuscular demonstrators. Fraunhofer ENAS was researching within two subprojects on miniaturized sensors, energy transmission and storage, communication, and last but not least on packaging and integration aspects as well as biocompatible encapsulation technologies.

eHarsh

www.enas.fraunhofer.de/eharsh

The lighthouse project »eHarsh« aims at developing and providing a technology platform, in which sensor systems are developed and manufactured for their application in extremely harsh environments. The consortium, consisting of seven Fraunhofer Institutes headed by Fraunhofer IMS, addresses the growing demand for smart control and communication techniques within the industry and our society, particularly in the Fraunhofer fields of research »Mobility and Transport«, »Energy and Resources« and »Production and Supply of Services«. Within the lighthouse project, robust sensors for the use up to 500 °C and MEMS sensors, integrated circuits and system components for the use up to 300 °C are developed and provided. At the same time, work on hermetically sealed encapsulations, 3D integration and encapsulations on a system level (»system-scaled package«), analytics, testing, reliability analyses and modeling is conducted. Fraunhofer ENAS is particularly working on MEMS acceleration sensors for geothermal energy (operation up to 300 °C) and the development of long-term stable hermetically sealed encapsulations with integrated ceramic windows for the sensor system as well as reliability studies.

High-Performance Centers

High-Performance Center »Smart Production«

www.leistungszentrum-smart-production.de

The High-Performance Center »Smart Production«, with the participating Fraunhofer Institutes IWU and ENAS as well as Chemnitz University of Technology, develops new technologies for the digitization of production processes. In future, the High-Performance Center will be a central hub for strategic research and technology transfer projects while actively involving SMEs and be a supporter for a sustainable transfer of innovation and knowledge into the industry. The goal of the High-Performance Center is transferring developments for digital industrial production processes from basic and advanced research to companies as quickly as possible.

Main topics and research objectives of the High-Performance Center are interdisciplinary and profile-forming research, digitization of production, smart factory, smart materials and Industry 4.0.

Moreover, strengthening of innovation and knowledge transfer, international recognition and sustainable positioning of the region, cooperation network for regional businesses and serving as an incubator for start-ups as well as attracting new talents and top researchers are overall in the focus of the work.

In 2019, the High-Performance Center will be expanded to become the High-Performance Center »Smart Production and Materials« and thus integrate the Fraunhofer Institutes IKTS and IWS as well as TU Dresden.

High-Performance Center »Functional Integration of Micro and Nanoelectronics«

www.leistungszentrum-mikronano.de

The High-Performance Center »Functional Integration of Micro and Nanoelectronics« started as a pilot project in 2016. The project, initially funded by the Free State of Saxony and Fraunhofer-Gesellschaft, will be converted into a transfer center and new projects will be the source of funding from 2018 until 2020.

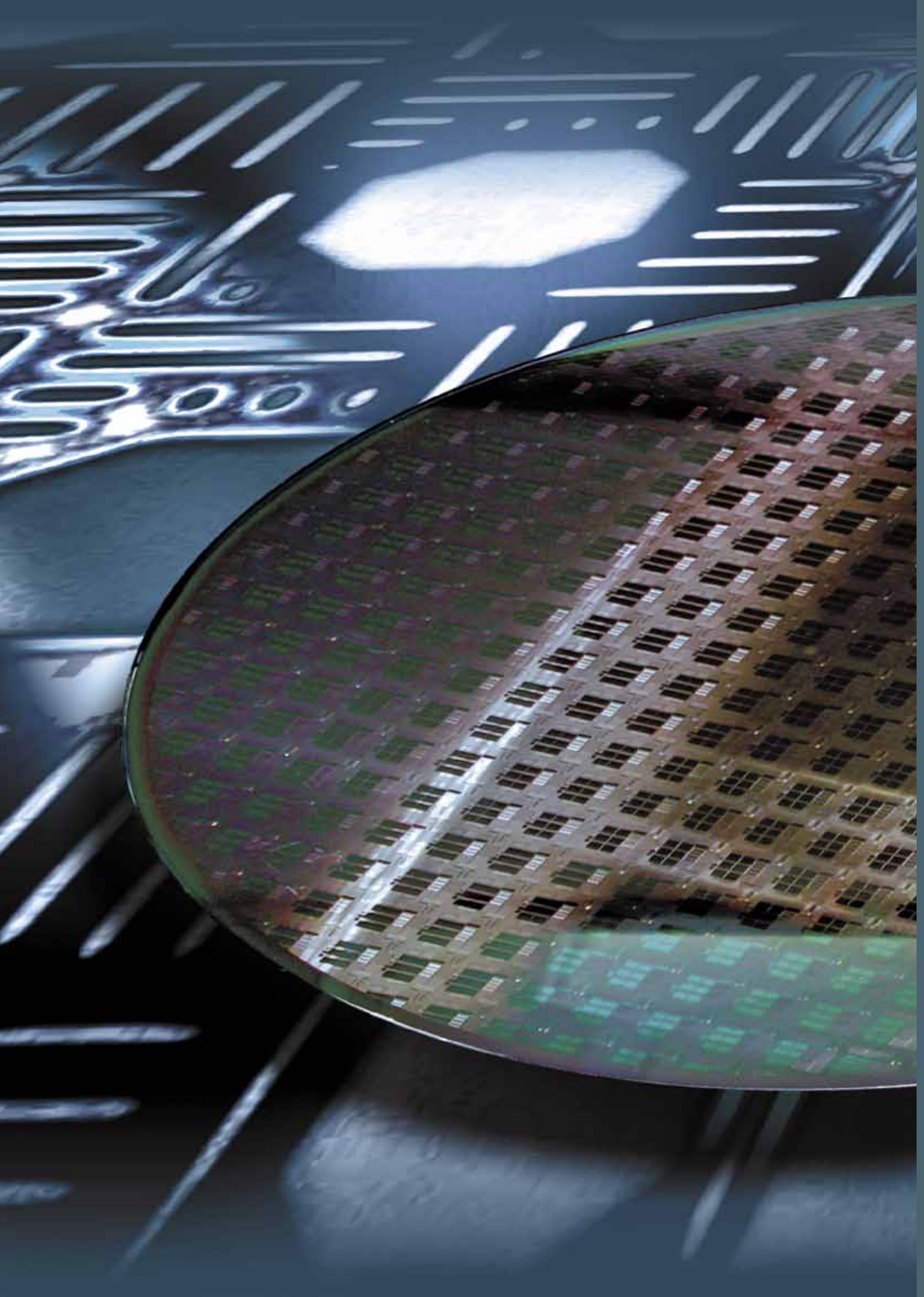
The High-Performance Center is situated in Saxony, a high-tech site for microelectronics. Alongside the value chain for microelectronic products and microsystems technology, it combines the expertise of the four Fraunhofer Institutes IPMS, ENAS, IIS-EAS und IZM-ASSID as well as the competences of the universities TU Dresden, Chemnitz University of Technology and the University of Applied Sciences Dresden (HTW).

The High-Performance Center is designed as an inter-institutional platform for the core competences system design, device and manufacturing technologies, system integration and reliability assessments. These core competences are particularly utilized in R&D projects of industry-related topics:

- Novel materials for new functionalities
- Modular, heterogeneous wafer systems
- Platform for ultrasonic sensors
- Integrated spectrometers with nano structures / optical systems
- Sensors / actuators in tools and machines

photo: iStock (Radachynskyi)

BUSINESS UNITS



MICRO AND NANOELECTRONICS

Micro and nanoelectronics is one of the key enabling technologies of the 21st century. The ongoing downscaling (More Moore), the integration of different functionalities (More than Moore) as well as the development of possible future technologies beyond the CMOS scaling limits (Beyond CMOS) are the ongoing development trends. The business unit micro and nanoelectronics is focusing especially on:

Processes and technologies for micro and nanoelectronics with the focus on back-end of line and interconnects

The development of individual processes (metal ALD, CVD, PVD, ULK processes, dry etching), novel concepts for diffusion barriers, alternative interconnect architectures for the reduction of parasitic effects and process and technology development for memristor crossbar arrays are the main focus of this topic.

Modeling and simulation of technological processes, equipment and devices

Experimental developments are supported by the simulation of processes and equipment (PVD, CVD, ALD, ECD). Furthermore, device simulation and modeling of CMOS and nano devices (i.e. CNT FETs) as well as blackbox modeling and event-driven modeling and simulation are realized.

Beyond CMOS and RF devices, integrated circuits and technologies

This topic comprises developments of memristive devices and circuits for neuromorphic computing and hardware security applications, RF MEMS switches as well as CNT FETs for analog high frequency applications.

Packaging and (heterogeneous) integration (2D, 2.5D, 3D) for electronic devices

This research and development area focuses on the development of processes for the integration of electronic devices for wafer level packaging, especially joining and contacting processes, thin film encapsulation and screen printing for metallization and solder.

Electromagnetic and thermomechanic characterization and reliability evaluation

This topic addresses back-end of line components, chip-package interaction and reliability assessment of board and system level. Both, the thermomechanical reliability analysis and optimal layout for electronic components, devices and systems and simulative thermoelectrical reliability on a system (PCB) and package level, are addressed.

BUSINESS UNIT MANAGER

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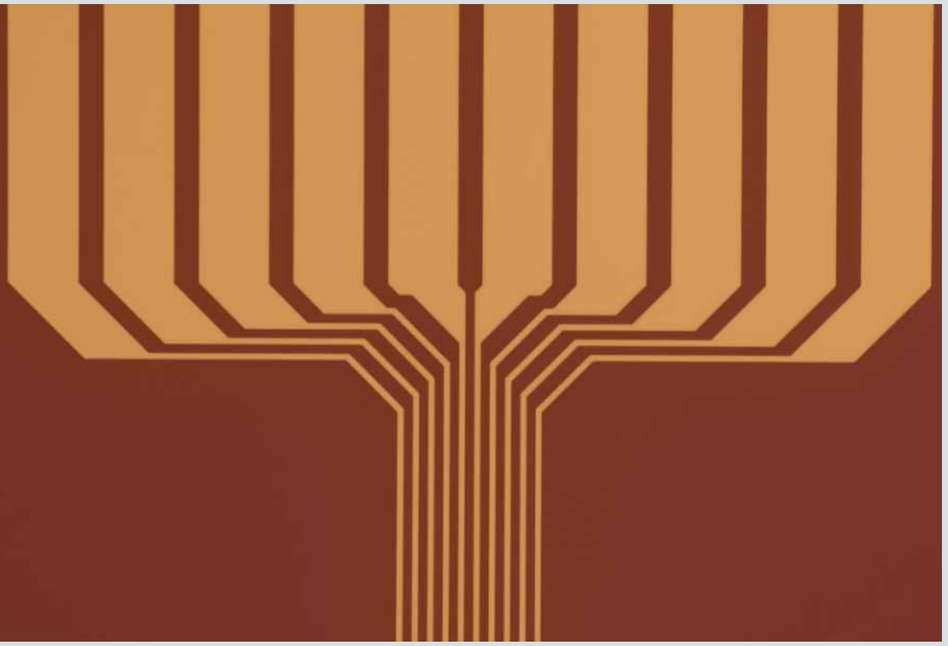
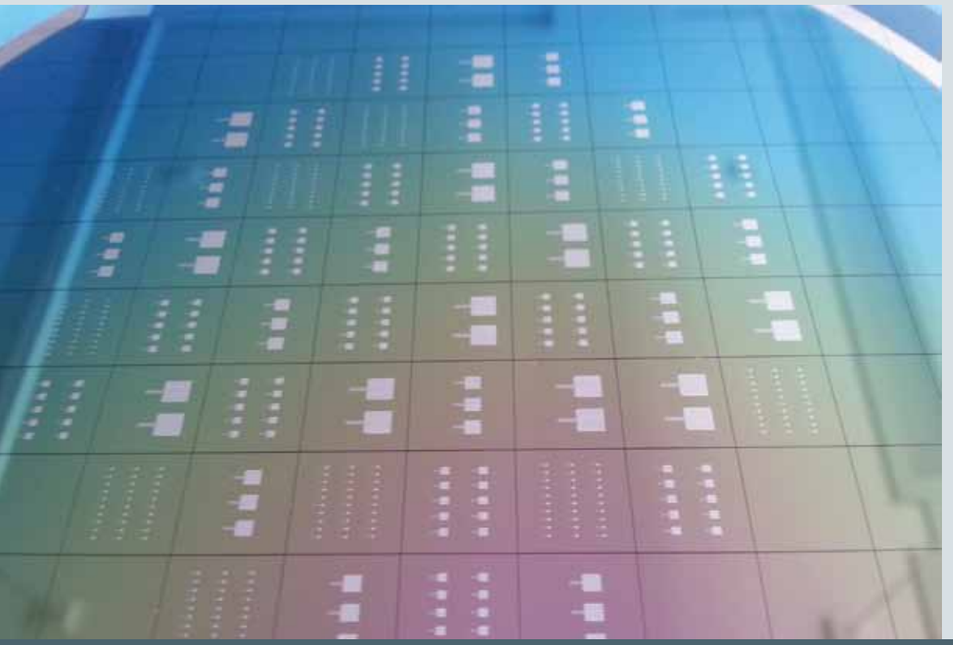


Top view on the structured bottom electrode for a 10 x 10 crossbar array.



Top view on a diced wafer with structured bottom electrodes for crossbar arrays of different sizes.

RESEARCH AND DEVELOPMENT

- **BEYOND CMOS**
- **PROCESSES AND TECHNOLOGIES FOR MICRO AND NANOELECTRONICS**

MICRO AND NANOELECTRONICS

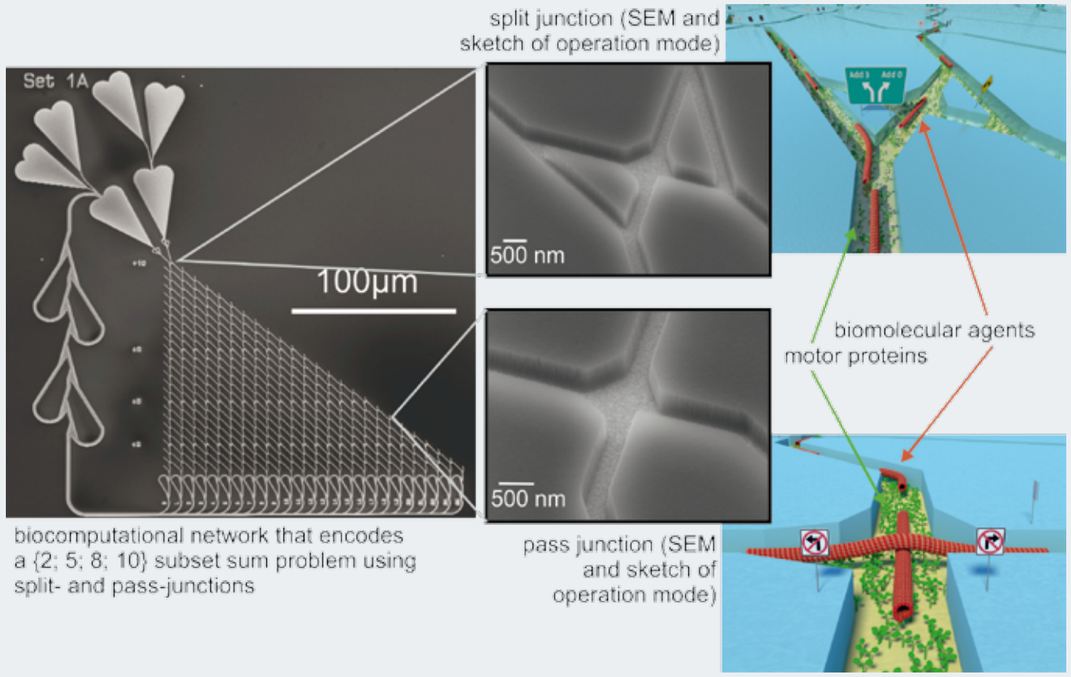
MEMRISTORS FOR THE COMPUTERS OF TOMORROW

In view of the increasing challenge in the miniaturization of conventional CMOS circuits, a further increase in performance through miniaturization is economically difficult and can only be maintained by large-volume production. As part of the worldwide digitization process, new concepts in data processing are investigated. Artificial intelligence and neuromorphic computing are keywords for new approaches alongside the established Von-Neumann-architecture. The integration of these technologies can succeed on the hardware side with new materials. Although their implementation in conventional industrial processes presents a great challenge, it also offers significant benefit for many applications.

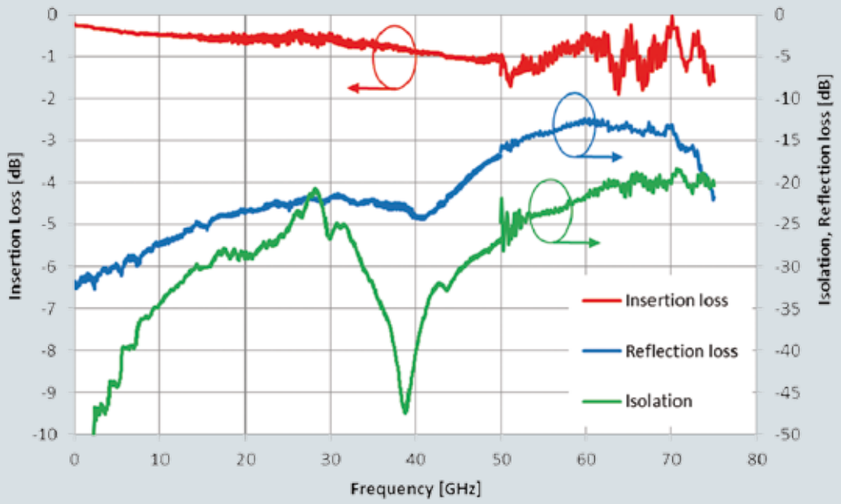
The material of our choice is $BiFeO_3$ (BFO). In addition to its well-known ferroelectric properties, it also shows voltage-pulse tunable resistivity. With specific modifications/doping in a MIM structure (Au/BFO/Pt) the material shows excellent retention, endurance, non-volatility and analog switching properties. The oxygen vacancies present in the material, as well as the dopant titanium introduced by diffusion, are of fundamental importance for the functionality of the structure. The integration of this type of memristor into a crossbar architecture allows simple direct addressing of the cells without the use of additional selection transistors. This is made possible by the inherent diode characteristic of BFO which significantly reduces unwanted sneak-path currents.

The choice of the deposition process and the determination of the deposition parameters of BFO at wafer level present particular challenges. The subsequent deposition of the top electrodes allows the completion of the crossbar architecture. The crossbar architecture is a basic element for many applications in the field of neuromorphic computing, reconfigurable logic and hardware-based security applications. A detailed knowledge of the electrical properties is a requirement for the implementation of these novel elements in software tools such like PSpice, on the basis of which reliable working circuits can be developed. In this case, for an accurate characterization of the state of the memristor in comparison to many ordinary CMOS devices, the currents/voltages applied in the past are of crucial importance, which currently makes exact modeling with common software tools very difficult.

The resistance change of BFO is of analogous nature, so that BFO memristors have comparable electrical properties as synapses in the brain. Due to the high non-linearity in the switching behavior of BFO, which can be explained by the ion drift model of Mott-Gurney, however, very fast resistance changes can be realized. With an increase of the applied voltage by a factor of 3, a reduction of the switching speed by 6 orders of magnitude to several 10 ns can be realized. This is much faster than the speed of synapses in the brain and indicate the potential of this new technology.



SEM-micrographs of the nano-channel-network fabricated by electron-beam-lithography (entire computational network, pass- and split-junctions). (left)
Sketch of the agent transport in the junctions. (right)



Measurement results of the scatter parameters of the RF MEMS switches, that represent the insertion loss and the reflection loss in the closed state and the isolation in the open state.

RESEARCH AND DEVELOPMENT

- BEYOND CMOS
- RF DEVICES

MICRO AND NANOELECTRONICS

FUNCTIONAL NANO STRUCTURES FOR BIOCOMPUTING

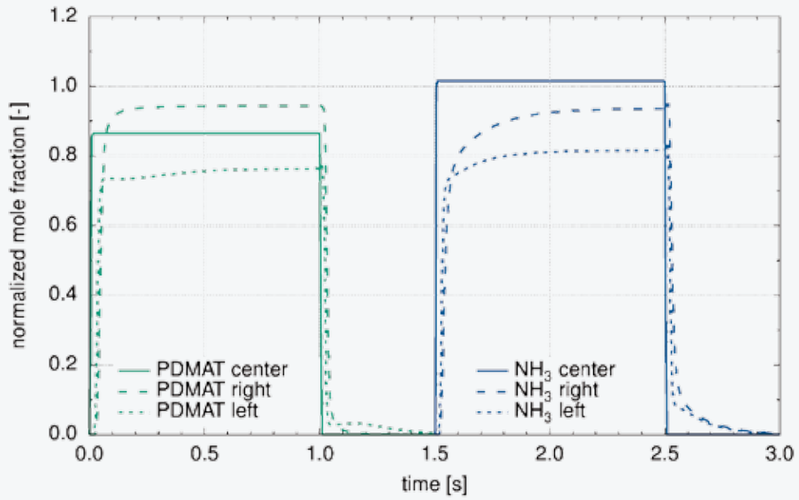
The EU-funded research project Bio4Comp aims to develop a device based on an approach called network-based bio-computation (NBC) to solve mathematical / combinatorial problems currently inaccessible to conventional computers due to its computational complexity. The idea is that biomolecular agents, each only a few billionth of a meter (nanometers) in size, explore a network that encodes the problem. Analyzing their routes through the network gives the optimal answer to the combinatorial problem. Due to the large number of independent biomolecular agents, propelled by molecular-motor-proteins, exploring the network in a highly parallel fashion, the solution will be obtained faster compared to conventional algorithms on computers. Notably, this approach uses orders of magnitude less energy than conventional computers, thus addressing issues related to power consumption and heat dissipation. This technique will be an excellent complement to microprocessor-based computers, particularly because miniaturization of ICs' is limited due to emerging quantum effects and rising costs. Therefore, Bio4Comp will lay the foundation for a new and innovative technology that has the potential to outperform electronic computers and may help us solve important practical problems such as the design and verification of circuits, the folding and design of proteins and optimal network routing.

This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 732482.

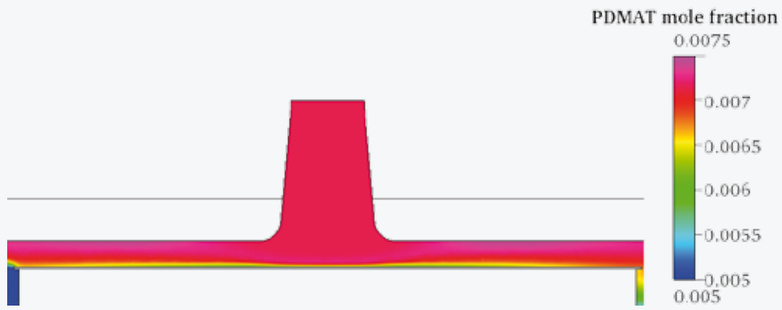
RF MEMS SWITCH

Fraunhofer ENAS developed a RF MEMS switch as a stand-alone component with hermetic encapsulation to implement it in micro wave and mm-wave systems. The chip is 3 mm x 1.5 mm of size and 0.5 mm thick. The switches are fabricated in MEMS technology at wafer level. A novel design of the contact area and of the RF wires is used to achieve a frequency span of the RF signals between DC and 75 GHz with an insertion loss of less than 0.5 dB up to 20 GHz and approx. 1 dB up to 75 GHz. Since the switch is a MEMS component with metal-metal contacts, a very high linearity with IIP3 > 65 dBm (1 GHz, 0 dBm) is provided by the device. The switch on and switch off time is approximately 10 µs, respectively. In comparison to RF switches at the market, this type of component needs lower actuation voltage (5 Volt without need of any step up converter) and extremely low actuation current (< 10 nA). The application fields are ranging from automated test equipment (switch matrix with very high frequency bandwidth, controllable attenuators) over antenna beam steering and agile antennas (controlling of the antenna pattern by phase shift of the feed line signals) to the reconfiguration of the front-end circuits of radio systems (antenna switches, filter reconfiguration).

Schematic and photographic representation of a modified process chamber with connected multi-pass optics (MPO) for plasma analysis by means of QCLAS.



1) Precursor (PDMAT) and co-reactant (NH_3) mole fraction during an ALD cycle at the wafer center, the right wafer edge and the left wafer edge (outlet position).



2) Precursor (PDMAT) mole fraction after dosing step with distinct precursor depletion above the wafer due to thermodiffusion.

RESEARCH AND DEVELOPMENT

- IN SITU PLASMA DIAGNOSTICS
- SIMULATION OF ALD

MICRO AND NANOELECTRONICS

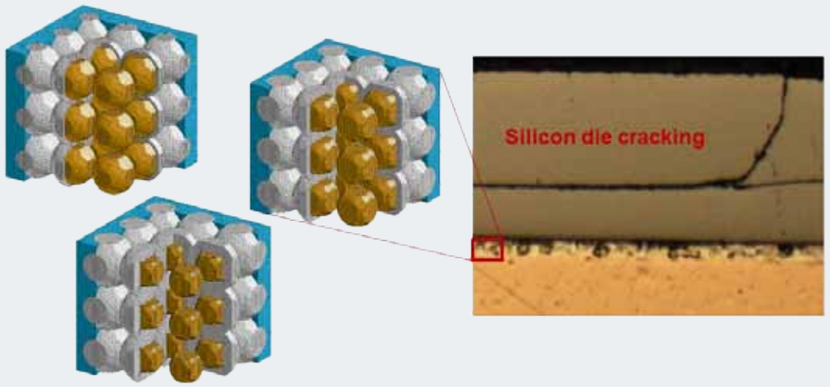
IN SITU PLASMA DIAGNOSTICS FOR 7 NM ETCHING PROCESSES

Challenges to process plasmas with regard to reproducibility, chamber conditioning or substrate quality are currently day-to-day business for semiconductor manufacturers. A defined control of plasma parameters seems to be the starting point to be able to also meet the more and more increasing requirements in the future. For this purpose, alternative in situ techniques with a high degree of sensitivity for industry must be tested and established. Motivated by this, process plasmas are analyzed at Fraunhofer ENAS using a spectroscopic method, which is not yet established in plasma analysis. Quantum cascade laser absorption spectroscopy (QCLAS) is used to determine chemical plasma parameters of molecular etching plasmas. The method provides direct access to the concentration and temperature of various process-relevant plasma species. In the project SeNaTe (Seven Nanometer Technology) dry structuring processes of so-called ultra low-k materials (porous materials of very low dielectric constant) are analyzed by QCLAS. The parameters measured during plasma treatment were correlated with the degradation state of etched samples. Thus, it could be shown that by measuring plasma species concentrations the polymerization on surfaces can be observed directly during the process. For the first time, a correlation between the radical temperature in the plasma chamber and the sidewall-degradation of structured substrates was observed. This result also raises a fundamental academic question, which needs to be investigated in further analyses.

Project: SeNaTe funded under H2020-EU.2.1.1.7.,
Grant agreement ID: 662338

SIMULATION OF TaN ATOMIC LAYER DEPOSITION FOR COPPER DIFFUSION BARRIERS OF 28 NM CMOS DEVICES

The progressing down-scaling of microelectronic devices leads to an increasing demand for deposition technologies which can produce uniform, homogeneous and ultrathin layers. Atomic layer deposition (ALD) has the capability to produce such layers even in features with high aspect ratio. In the EVOLVE project together with the chip manufacturer GLOBALFOUNDRIES, the Fraunhofer IPMS-CNT and the TU Dresden, we investigated a TaN ALD process for the manufacturing of copper diffusion barriers using reactor scale simulation. Using simulation, we were able to analyze the precursor distribution during dosing and purging steps in a top-injection single-wafer reactor. We experienced a reduced precursor concentration directly above the heated wafer in our simulation. A high temperature gradient is observed above the wafer due to the temperature difference between the hot wafer (200 °C) and the colder gas inlet (90 °C). Temperature gradients cause thermodiffusion, where the larger molecule (precursor) diffuses from the hot area (wafer) to the cold area. Using reactor scale simulation, we were able to get useful insights into the field of reactor flow and the precursor distribution, which would not be possible otherwise. Based on these findings, further process optimization steps will be performed.



Optimizing silicon die cracking risk by tailoring of copper particles and intermetallic compound content in a die-bond layer.

This newly developed method for local measurements scales the macroscopic bulge test into micro technical magnitudes.

Multiscale concept.

RESEARCH AND DEVELOPMENT

- **RELIABILITY EVALUATION**

MICRO AND NANOELECTRONICS

THERMO-MECHANICAL RELIABILITY ASPECTS OF HIGH TEMPERATURE INTERCONNECTS BY TRANSIENT LIQUID PHASE SOLDERING

Increasing the maximum reliable operating temperature is a key issue in increased efficiency of power modules and devices applied in upcoming developments such as electrical drive systems, smart lightening, or energy management systems. In parallel to the development of semiconductors with higher operating temperatures, interconnection technologies are being developed to create solutions along the value chain. High temperature interconnection technologies in series application are silver sintering, while other sintering materials or interconnections based on the formation of intermetallic compounds (IMCs) are still under development. The latter technology can be applied in form of transient liquid phase soldering (TLP soldering), i.e. IMCs Cu_6Sn_5 or Cu_3Sn are formed by isothermal solidification. Standard soldering temperatures (approx. 250 °C) lead to high-temperature resistant connections > 400 °C. However, material behavior of the intermetallic compounds differ from soft solders or sintered silver. In particular, they are less ductile and high mechanical stress can built up after processing or during operation. Therefore, new reliability issues due to less compliant interconnects occur and lead to silicon die fracture or metallization delamination. By use of micro-mechanical modelling tailored transient liquid phase materials can be composed to reduce the failure risk.

Project:
NanoEIS+ sponsored by VDI/VDE,
in collaboration with CWM,
FKZ: 13XP5002B

MULTISCALE RESIDUAL STRESS ANALYSIS IN THIN FILM LAYERS

In modern technologies, thin films and multilayer structures are important for the functionality of micro- and nanosystems. Such thin layer constructs are generally subject to residual stresses, which can lead to damage, delamination or failure of the film or membranes. This can occur at all scales, from macro-, micro-, to nanoscale. For the latter case, residual stresses in thin films can differ greatly of that found in bulk materials. Furthermore, local stresses and stress gradients play a decisive role in various thin film properties. However, those inherent stresses are usually unknown, even if they decisively influence the material and system performance. The knowledge of the residual stresses is essential for the reliability and robustness of the systems.
The fibDAC method is a high-resolution, direction-resolving, residual stress analysis on surface layers and layer stacks used on micro- and nanoscale. This method, a combination of Focus Ion Beam micromilling, extensive strain analysis by means of digital image correlation (DIC) and analytical / numerical models for residual stress calculation, is being optimized at Fraunhofer ENAS and is on the way to be qualified.
For local measurements on macro- and microscopic scales, a combined optical method is used. This newly developed method scales the macroscopic bulge test into micro technical magnitudes. It uses a chromatic sensor for deformation detection along the out of plane axis and a digital image correlation, based on an optical observation (HD video camera), simultaneously asses the in-plane deformation. Analogous to the fibDAC, the material parameters can be obtained by comparing experiments with analytical solutions (FEM).
Last axis of development, the multiscale concept, which was developed within the NanoEis+ project in cooperation with CWM, is able to determine global properties of a system, as well as to detect local inhomogeneities and complex residual stress distributions, allowing us to adequately assess all inherent stress-related influences on the functionality and failure behavior.

SENSOR AND ACTUATOR SYSTEMS

The business unit comprises manifold sensor and actuator systems, which are based on different technologies and transducer principles as well as procedures, methods and sensor technologies for material and structural analysis. The prospective focus lies on an increasing integration of nanostructures. The following topics are addressed:

Inertial sensors || This topic focuses on the development of high precision silicon-based sensors for measuring acceleration, vibration, inclination and angular rate. The value chain, starting with the design of the MEMS or system, the development of technologies as well as the manufacturing of prototypes, followed by the characterization and testing of the system, is fully covered.

Optical systems/MOEMS || Optical systems/MOEMS are well-established silicon-based systems, i.e. variable frequency optical filters and shutters based on optical Bragg reflectors which are complemented by light sources and detectors. Furthermore, quantum dot-based LED and photo detectors enable customer specific spectral sensors, material integrated light sources as well as design and display devices.

Electromagnetic sensors || Multi-dimensional magnetic sensors based on the GMR and TMR effect, respectively, while using ferromagnetic thin films, are in the focus of this topic. However, they can be applied both in the direct measurements of magnetic fields and in the measurement of distance, position and rotation. Furthermore, sensors for near field measurements of electromagnetic fields and determination of radiation characteristics were developed.

Pressure and power transducer || Silicon-based ultrasonic transducer and ambient pressure-sensitive resonators as well as MEMS loudspeaker are developed. Speakers are based on novel materials and technologies, i.e. sputtered metallic glass and printed permanent magnetic layers.

Material and structure sensors || This topic includes methods, techniques and arrangements for material and structure sensors. The sensors for mechanical strain, stress and overload (detection of cracks) are based on silicon technologies. Nano composite-based overload sensors as well as humidity sensors are using thin layers of organic materials with embedded nano particles enabling the integration into fiber-reinforced composites. Another approach are sensors based on carbon nanotubes.

BUSINESS UNIT MANAGER

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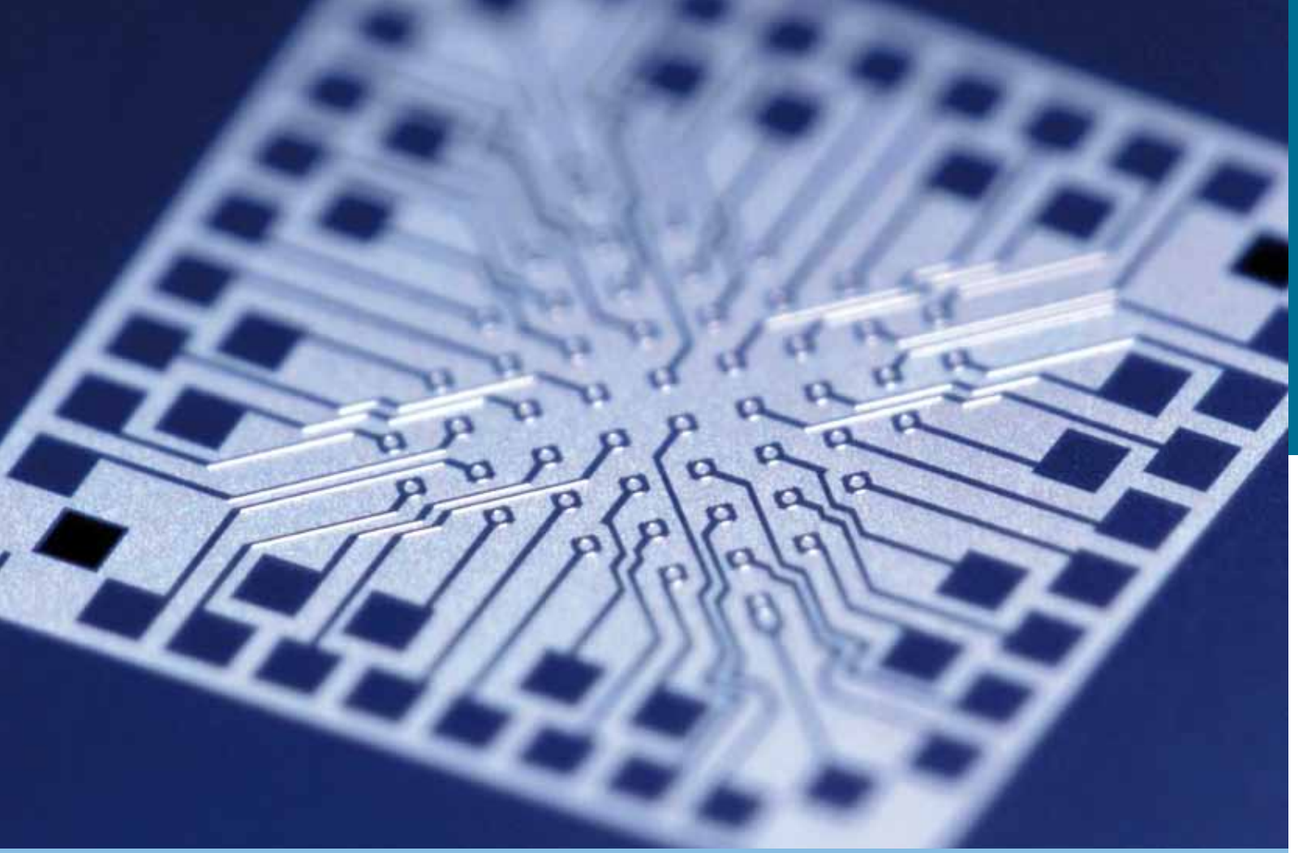
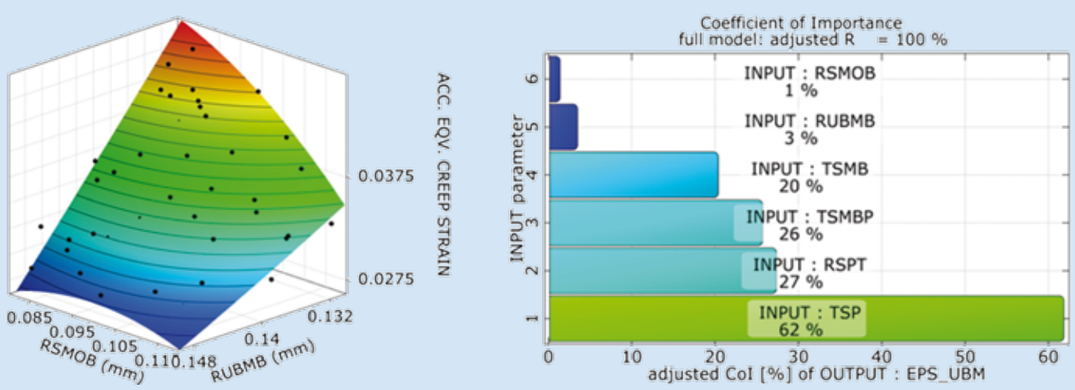


Piezoelectric micromachined ultrasonic transducer are microsystems using piezoelectric materials for an acoustic mapping of the environment.



Sensitivity analysis and optimization based on finite element modulation.

RESEARCH AND DEVELOPMENT

- **ULTRASONIC TRANSDUCER**
- **DESIGN FOR RELIABILITY**

SENSOR AND ACTUATOR SYSTEMS

PMUT – A NEW GENERATION OF ULTRASONIC TRANSDUCERS

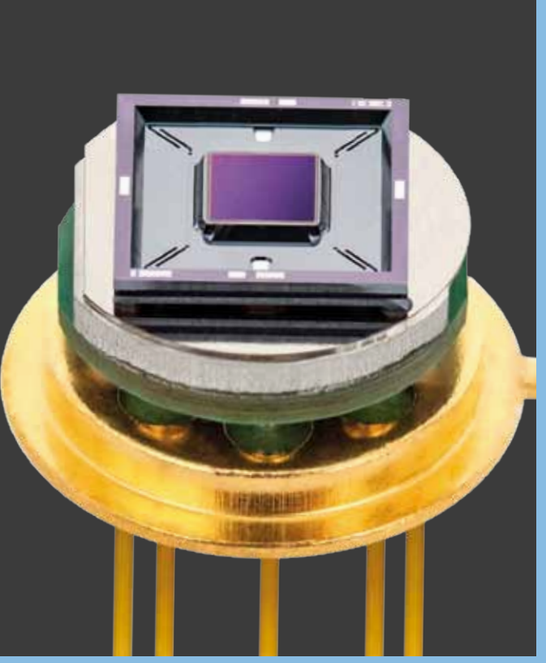
PMUT (piezoelectric micromachined ultrasonic transducer) are microsystems using piezoelectric materials for an acoustic mapping of the environment. Compared to bulk ultrasonic devices the PMUTs are better to integrate, e.g. for medical imaging devices. Furthermore, they are smaller with higher resolution. This development enables medical, endoscopic in vivo imaging devices and ultrasonic radar for autonomous mobility and industrial machines. In contrast to capacitive microsystems (CMUTs) the PMUTs require low voltages.

By actuating PMUTs with an electric voltage, an acoustic wave is transfered into the surrounding gas or fluid. Scanned objects will reflect the acoustic wave. The reflection signal will actuate the PMUT. The microsystems piezoelectric layer vibrates and generates a sensor signal. The distance of microsystem and object can be analyzed by measuring the time delay between actuating the PMUT and sensing the reflected signal. An array arrangement of PMUT sensors and actuators enables to map the environment.

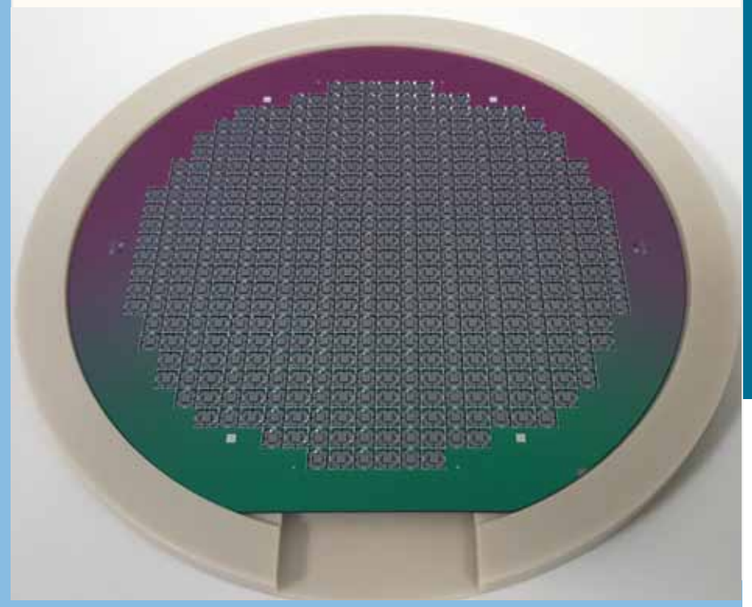
The researchers of the Fraunhofer ENAS and the Center for Microtechnologies (ZfM) at the Chemnitz University of Technology use piezoelectric Aluminum nitride (AlN). This transducer material is highly suitable for the integration into existing MEMS processes. The moderate piezoelectric coefficient and low dielectric constant of AlN is optimal for applications, which require a combination of sensors and actuators.

AUTOMATED VIRTUAL PROTOTYPING FOR NEW PACKAGE GENERATIONS

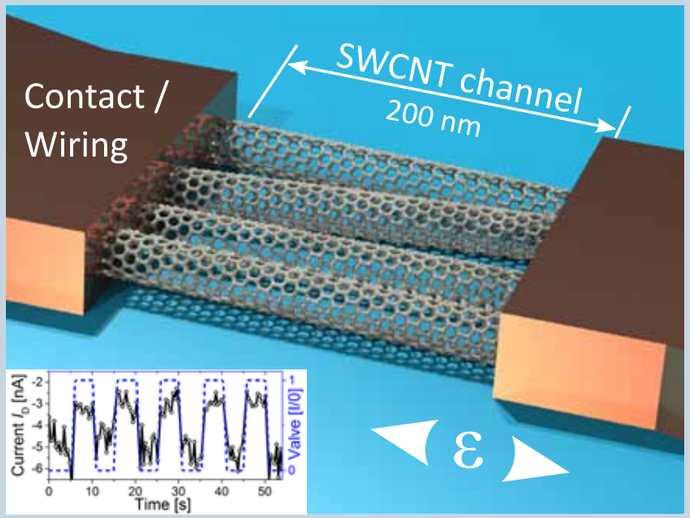
Ever expanding demands for smart systems in different applications require highly miniaturized electronic solutions with new capabilities and technologies. System-in-package (SiP) products based on fan-out-wafer-level-packaging (FOWLP) technologies are able to meet many of the functional and performance requirements. For the reliability of these SiPs, the excessive warpage and thermo-mechanical stresses caused by temperature changes in fabrication, test, and service need to be assessed during the development of each new SiP product as part of its qualification process. Automated virtual prototyping based on finite element (FE) simulation allows analyzing the thermo-mechanical situation during production, test, and service within some hours and even prior to the fabrication of physical samples. The objective of virtual prototyping is to replace time consuming experiments (e.g. thermal cycle tests taking months) by fast simulations. The developed method of virtual prototyping involves the material characterization by dynamic mechanical analyses in order to deduce the relevant viscoelastic material properties, experimental warpage measurement of a SiP using the MicroProf measurement system and finite element (FE) analysis using a fully parametric FE model of SiP by modular system of models in ANSYS. Also, the FE model is validated with experimental results that proves the simulation findings to be as trustworthy as the practical sample tests. Finally, the sensitivity analyses and design optimization can be performed, which allows identification and calibration of all essential parameters for optimized SiP.



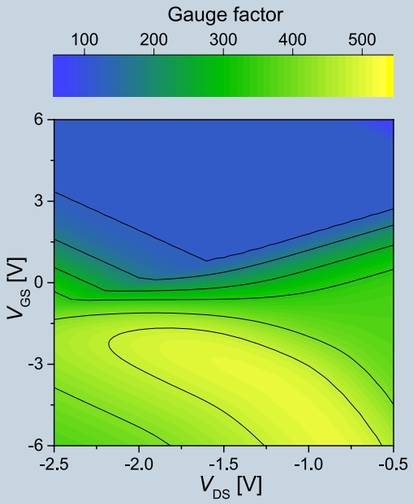
FPI and detector in a TO39 housing.
(by courtesy of InfraTec GmbH, www.InfraTec.de)



Processed wafer.



Scheme of the fabricated CNT sensor on top of a MEMS membrane and typical sensor response curve.



A calculated sensitivity map at different operation regimes.

RESEARCH AND DEVELOPMENT

- OPTICAL COMPONENTS / MOEMS
- MATERIAL AND STRUCTURE SENSORS

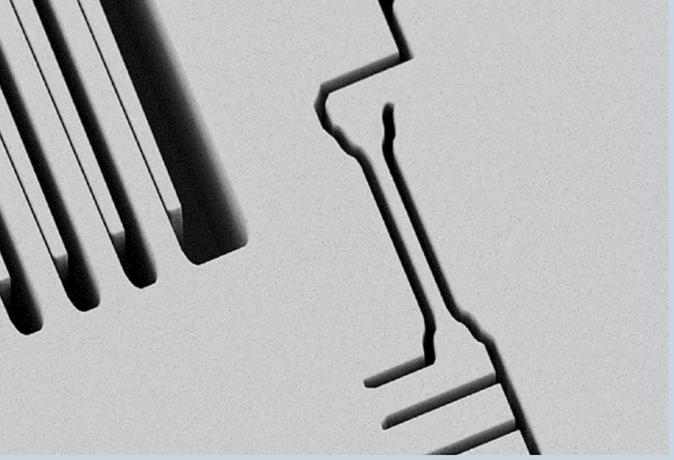
SENSOR AND ACTUATOR SYSTEMS

FABRY-PÉROT INTERFEROMETER FOR SENSOR APPLICATIONS IN THE INFRARED SPECTRAL RANGE ON THEIR WAY TO FURTHER MINIATURIZATION

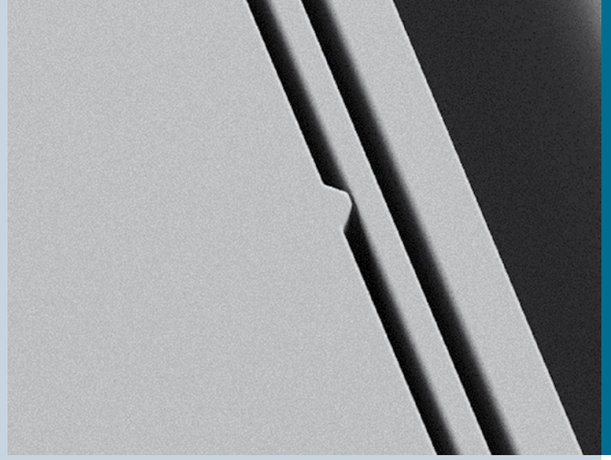
The Fabry-Pérot interferometers (FPI) fabricated in Chemnitz are used for narrow band filtering of electromagnetic radiation in the visible and infrared wavelength ranges. The spectral range can be tuned continuously by electrical voltage. In particular for applications in the infrared range, very small, robust and inexpensive spectral sensors can be produced e.g. in combination with single-point detectors. Fraunhofer ENAS cooperates with the companies InfraTec GmbH Dresden, Jenoptik Optical Systems GmbH Jena and the Center for Microtechnologies of the Chemnitz University of Technology to achieve a further miniaturization of the MOEMS in a new FPI generation by an optimized and compact design. While maintaining a large optical aperture of 1.8 x 1.8 mm², the chip size of 7 x 7 mm² could be reduced to only 5 x 5 mm², so that 460 chips can be processed on a 6-inch wafer. By using an arrangement with two movable reflector carriers, the FPI distinguish themselves by a simple control with low voltage requirement and a good robustness against the influence of gravity. By adapting design parameters and the optical layer system, the working range of the filters can be adapted to customer-specific requirements. The entire spectrometer can now be accommodated in a TO39 housing. Applications of the miniaturized FPI can be found e.g. in mobile spectrometers for gas analysis in medical engineering, fabrication process control and safety technology.

CARBON NANOTUBE GIANT PIEZORESISTIVE STRAIN SENSORS

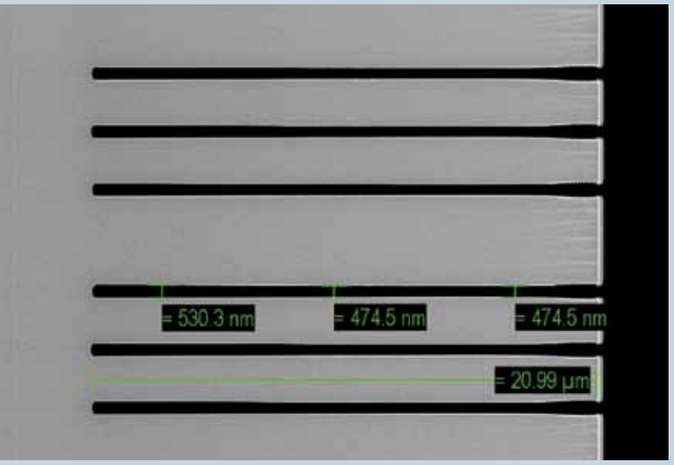
The scalable fabrication of electronics and sensors in the context of Industry 4.0, the Internet of Things and for flexible/wearable electronics requires innovative approaches for the integration of new materials. One of these approaches is the integration of functional nanomaterials such as single-walled carbon nanotubes (SWCNTs). The intrinsic properties of SWCNTs, such as a high Young's modulus, ultimate mechanical strength and the intrinsic giant piezoresistivity facilitate a new class of highly-miniaturized strain sensors standing out by versatile integration capabilities on different substrates or in complex systems. In recent years, Fraunhofer ENAS developed a technology platform for the scalable integration and characterization of CNTs on wafer level in cooperation with Chemnitz University of Technology. The superior performance of membrane-based carbon nanotube sensors characterized by gauge factors of up to $\beta = 800$ ($\beta = \Delta R\, R_0^{-1}\, \varepsilon^{-1}$) exceeds the sensitivity of conventional silicon based strain sensors by half an order of magnitude. In continuing investigations, which combine technological and theoretical approaches, sensor operation regimes are explored where the intrinsic sensitivity is further enhanced to up to 150 percent. Different integration scenarios are available to integrate these miniaturized sensors onto a wide variety of substrates and materials. For example, efficient condition monitoring of safety-relevant applications is conceivable due to their low energy consumption and footprint.



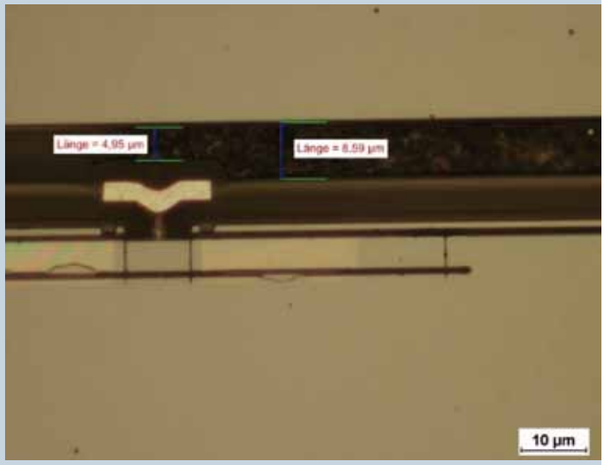
Flexible suspension with optimized stress compensation for high g application.



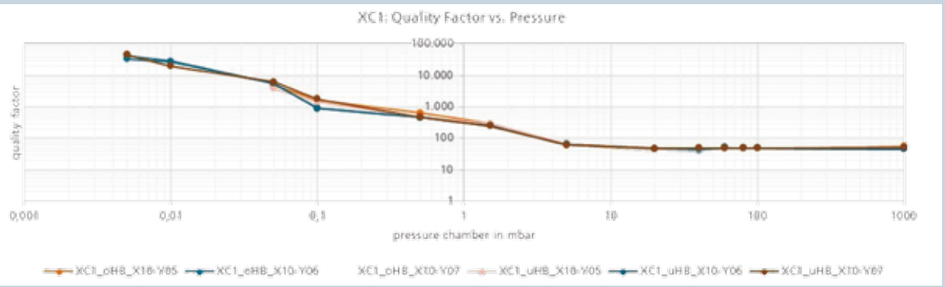
Example for motion stoppers with flexible counterpart.



Sub-micron trenches with high aspect ratio etched into single crystalline Si.



Cross section (detail) of the glass frit bond between sensor wafer and cover wafer.



Evaluation of the pressure dependency of the quality factor for selected sensor dies. (by courtesy of Infineon Technologies Dresden)

RESEARCH AND DEVELOPMENT

· INERTIAL SENSORS

SENSOR AND ACTUATOR SYSTEMS

INTENSE2020 – DEVELOPMENT OF ROBUST ACCELERATION SENSORS FOR AUTOMOTIVE APPLICATIONS

In February 2018, Fraunhofer ENAS together with the Center for Microtechnologies (ZfM) of the Chemnitz University of Technology and the industrial partner Infineon Technologies Dresden have started a research and development project on acceleration sensors. These sensors will have large measuring ranges (up to 500 g) as a well as a high shock resistance (> 3000 g in use) and aim for the application in autonomous driving systems. The acceleration sensors will be part of in-tire systems together with Infineon pressure sensors. With the required resolution these sensors will provide relevant insights on the cars speed, the road condition and even the current position of the tire. This requires the detection of accelerations in all three directions integrated in one MEMS chip.

The research partners from Chemnitz are working on innovative solutions for sensor design, such as robust design of the flexible suspension of inertial masses and flexible movement stoppers. The ongoing minimization of the width of etched gaps down to the sub-µm range together with the progress of increasing the aspect ratio up to approx. 40:1, very small, compact and sensitive capacitive sensor elements are developed. Technological scaling experiments of important geometric parameters based on established cavity SOI technology help to determine the technological limits of meaningful minimization. Another focus is put on concepts for minimizing stress influences by means of design and technology optimization.

For the development of an optimal low-stress encapsulation of the sensors at wafer level, integration concepts based on wafer bonding processes (direct and eutectic bonding, glass frit bonding) are being developed. They will be compared to a novel surface micromachined g-sensor with a monocrystalline seismic mass, developed by Infineon. In a first test run, sensors manufactured in Dresden were provided with an additional structured lid wafer applied by glass frit bonding. The glass frit layer was able to compensate for a height relief of more than 3 µm produced by the thin-film structure. Over the next two years, the focus will be on implementing and demonstrating novel approaches for the integration to minimize space requirements for bond and bond sites.

Together with the partner in Dresden, the sensors undergo extensive metrological characterizations. Fraunhofer ENAS, for example, has comprehensive experience in electrical and optical wafer level testing of sensor parameters such as capacitance, eigenfrequencies and quality factors. There is a setup used for electrical measurements of wafer level quality factors in the vacuum chamber on open and encapsulated sensors, the pressure dependence of this important sensor parameter can be determined and compared with the predicted and expected values. Another focus will be the characterization of system parameters of assemblies with MEMS from both production sites at Infineon Dresden and at ZfM in Chemnitz.

With solution approaches to design, technology and characterization of the new sensors, the Chemnitz partners want to make a significant contribution to the effective sensor development and thus for an improvement of the mobility and driving safety of our vehicles of the future.

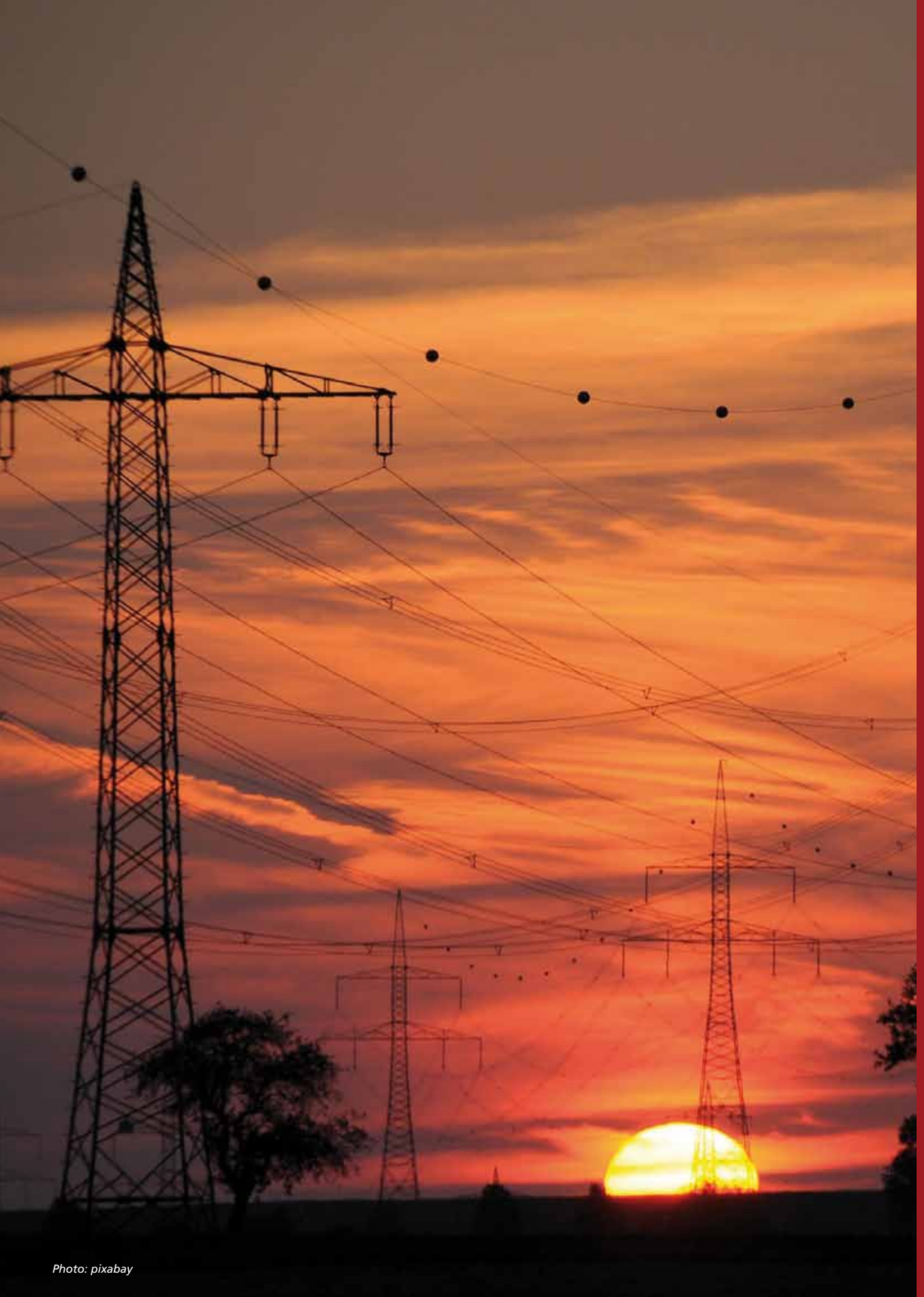


Photo: pixabay

TECHNOLOGIES AND SYSTEMS FOR SMART POWER AND MOBILITY

Know-how and technology transfer and development of research samples and prototypes in the field of generating and transmission of electric power and in the field of transportation are the main services of the business unit »Technology and System for Smart Power and Mobility«. The focus is put on systems for monitoring of electric power lines, on the integration of actuators for active flow control, on the optimization of the reliability of high power electronics. Fraunhofer ENAS, together with partners, develops smart sensor systems for monitoring of high voltage and medium voltage power lines including the transmission of data into the grid control center. Such sensor systems are used for increasing the ampacity of existing power lines, for the detection of ice load and for the enhancement of safety and reliability of the electric grid infrastructure. Partial discharge, abnormal temperature change, vibration and motion and ground faults are detected, localized and evaluated on site. The activities include the development of monitoring systems for high voltage overhead lines, middle voltage overhead lines and middle voltage cables and connectors with focus on reliable and cost-effective systems.
A further topic deals with the improvement of aerodynamic conditions of vehicles. In case of high speed cruise, the largest amount of driving power of aircrafts and cars and trucks is dissipated by the surrounding air flow and vortexes. The influence of the air flow bears a high potential of power saving. Different approaches are pursued by using of Synthetic Jet Actuators to influence the vortex by a multitude of small synthetically generated crossflows. It aims to optimize the air flow around the vehicle. Moreover, it turned out that the efficiency of wind power plants can be increased by active flow control when the flows around the blades is optimized by such technology.
A further aspect is the development of methods to analyze suspected reliability issues of high power electronics and modules applied in electric vehicles. It offers novel approaches to detect cracks, delamination and overheat situations by computer simulation in advance and as a part of the design procedure of such systems. The methods include the combination of different detrimental effects as like as thermo-mechanical stress and fast change of stress conditions, the combination of load power, temperature change and external mechanical load and vibrations and the experimental evaluation and practical analysis.

BUSINESS UNIT MANAGER

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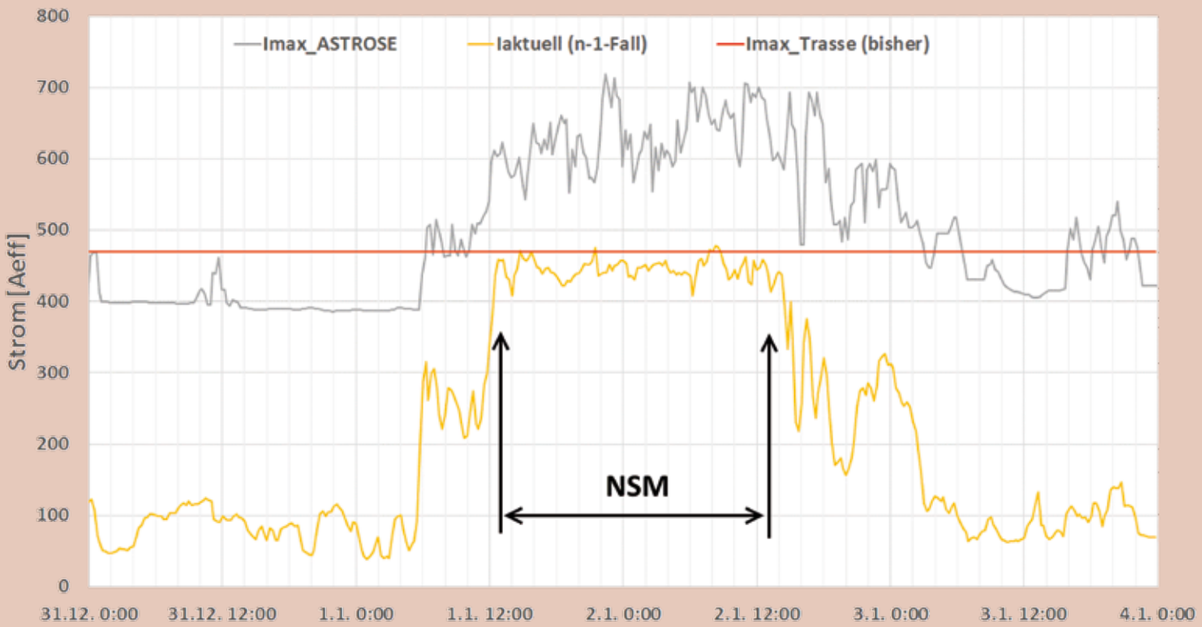


Existing electricity reserves by ASTROSE® system could have prevented network security management events.

RESEARCH AND DEVELOPMENT

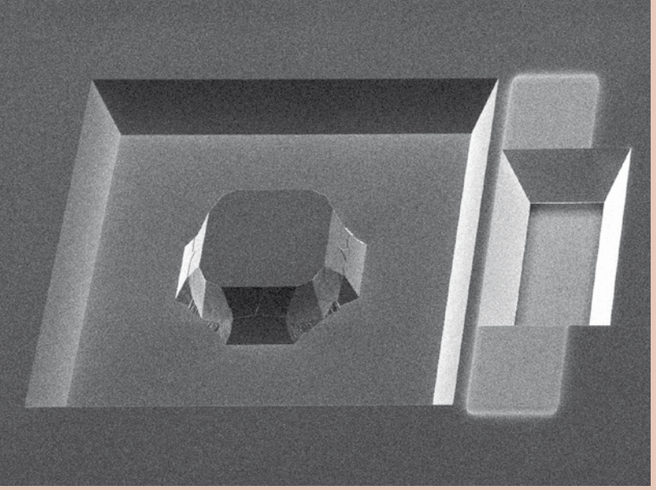
- **POWER LINE MONITORING**

ALGORITHMS FOR THE MONITORING SYSTEM ASTROSE® IN ORDER TO INCREASE THE CURRENT CARRYING CAPACITY OF OVERHEAD POWER LINES

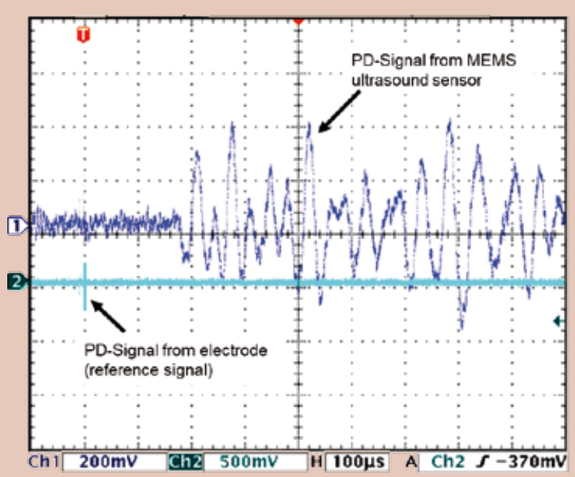
The self-sufficient sensor network ASTROSE® was developed in a research project and has been used in a pilot test with 59 sensor nodes since September 2014 on a 110 kV overhead power line in the Harz mountains in Germany. Each sensor node measures the temperature, the inclination of the conductor and the current flowing through the conductor. The measurement data is transmitted by radio from sensor node to sensor node to the base station. In the past, the data were used to evaluate the system for technical robustness and reliability. In order to achieve a commercial benefit by the application of such monitoring systems, the evaluation and further processing of the sensor data is necessary. The above mentioned measurement data primarily reflect the temperature of the conductor, the sag, the tensile force of the conductor and further mechanical loads if they derive from ice loads as an example. Moreover, the combination and fusion of measurement data and environmental condition data allow to determine the power line ampacity online.

Recently, a software module was developed together with the Fraunhofer IZM, which determines the cable temperature of each span field and the ampacity of the power line. This enables the grid operator to detect weak points in the grid (e.g. span fields with a too high cable temperature) and to exploit the reserves that arise in the energy transmission net depending on current weather conditions. The developed software module is currently in the evaluation phase. During this development and evaluation an indication parameter for the data reliability is transmitted in addition to the measurement data to the grid control centre which indicates particular situations that may lead to misinterpretation of the sensor data.

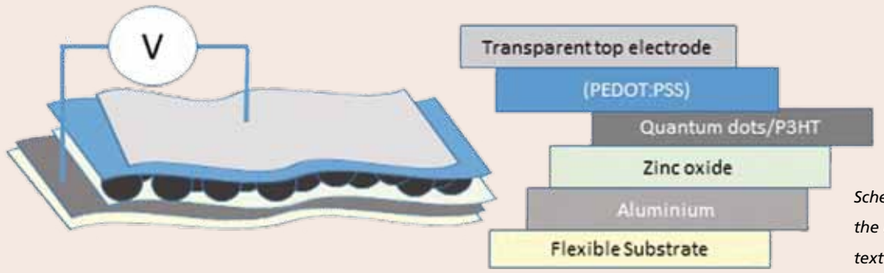
The first tests and data reviews show that the actual ampacity is much higher than the maximum rated ampacity of the overhead line. Shut down or the reducing of the power generation of wind power stations as part of the network security management measures could have been prevented. The figure on the left page shows such situation as an example. The rated maximum current is given by the red line in the diagram. The (n-1)-current (yellow curve) is calculated based on the actual grid situation by the grid control centre. It is the maximum current that may occur if one mayor component of the power grid fails. The grid control centre regulates the sources and the load such way that the (n-1)-current is always below the rated maximum current. The diagram show a sudden rising load on January 1st 12:00 pm that is limited to the rated maximum current by the grid control centre as part of the network security management till January 2nd 12:00 pm. Such kind of relief measures are regularly done by reduction of the power of wind power plants. The monitoring system indicates that it is more than 100 A higher than the rated maximum current of the power line in the period of time between January 1st and January 2nd that is caused by chilling of the conductors due to strong wind. In case of the given example, the power relief would not have been extended that way.



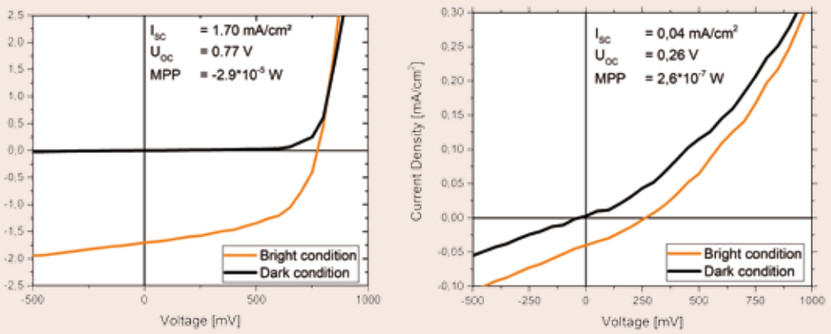
SEM view of the MEMS ultra sound sensor with the membrane, the rigid body in the center of the membrane and the contact areas (right).



Screenshot of the oscilloscope showing the PD signal from an electrode based detection system (light blue) and the PD signal from the MEMS ultrasound sensor (dark blue).



Schematic representation of the layer stack onto technical textile.



Solar cell characteristics onto PET-ITO-foil (left) and onto technical textiles (right).

RESEARCH AND DEVELOPMENT

- **POWER LINE MONITORING**
- **CUSTOMIZED FLEXIBLE SOLAR CELLS**

TECHNOLOGIES AND SYSTEMS FOR
SMART POWER AND MOBILITY

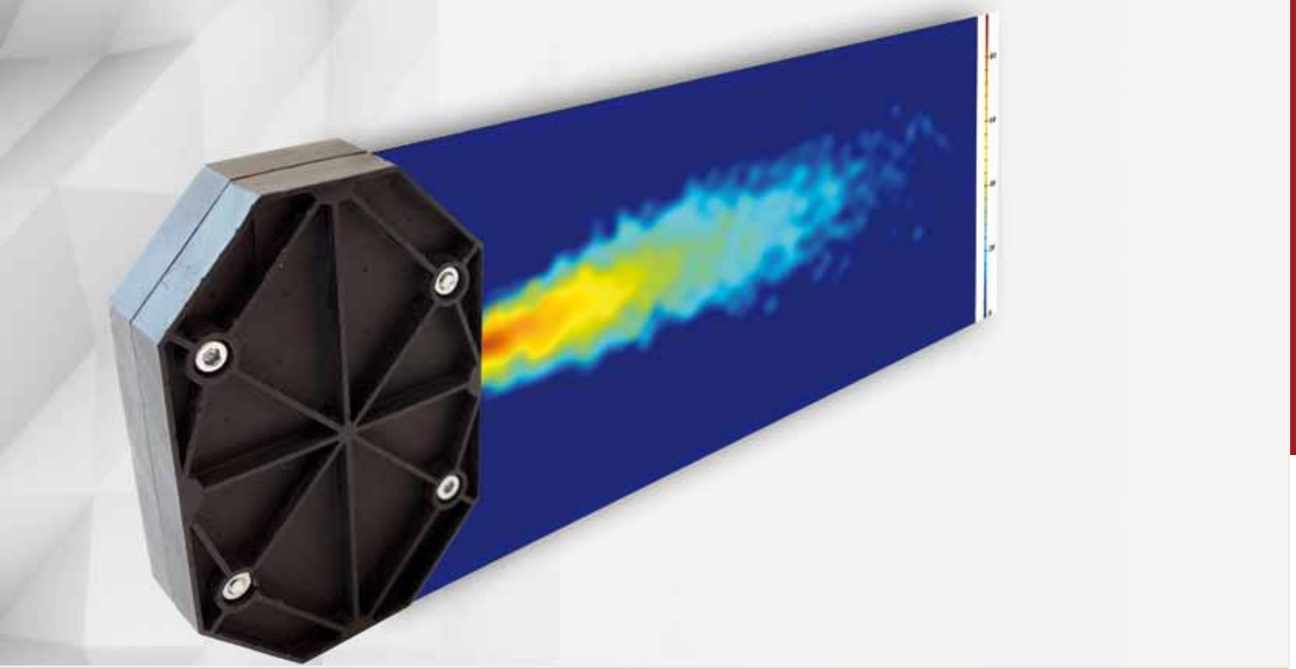
PARTIAL DISCHARGE SENSOR USING AN IMMERSED MEMS TRANSDUCER

Different principles of the detection of partial discharges within oil filled operating supplies for middle voltage and high voltage application (transformers, Peterson coils) are followed so far. The detection of the electromagnetic wave caused by the partial discharge by electronic means and the detection of structure born sound at the outer side wall of the case are the commonly used ones. The noise is generated by the intensive heating of the oil within the electric current channel during the partial discharge and spreads throughout the oil. This investigation reports about the use of a low cost MEMS ultrasound sensor, that is immersed in the oil. The MEMS sensor contains a silicon membrane with a rigid body in the center and applies a capacitive read out. The membrane is fabricated by etching. The counter electrode is built by a second silicon part beneath the membrane part. Silicon direct bonding with an intermediate SiO_2 layer is used to fabricate the devices at wafer level. The right figure shows the signal from the MEMS ultrasound sensor and a signal of the partial discharge that has been detected by an electric probe as reference signal and to trigger the signal recording. The partial discharge was set to approximately 1000 pC in this case. The output signal of the MEMS ultrasound sensor is time delayed due the limited speed of the sound in oil.

TRANSFER OF QUANTUM DOT-SENSITIZED SOLAR CELLS ONTO TECHNICAL TEXTILES

Today, silicon-based solar cells are widely used for energy harvesting in real life applications. Because of their high processing costs researchers are looking for alternative materials and solar cell systems. For a few years, nanomaterials like Quantum Dots are used as absorbing materials inside solar cell layer stacks. The absorption properties can be tuned by changing the quantum dot size and material composition. At Fraunhofer ENAS, quantum dot solar cells were realized onto technical textiles in the frame of the BMBF-project called »PhotoTex« in order to directly integrate an additional function. A hybrid quantum dot/polymer-based system was chosen which can be processed at low temperatures and which does not need a liquid polyelectrolyte. The solar cell layer stack consisted of: Transparent electrode/PEDOT:PSS/quantum dots-P3HT/zinc oxide/aluminium.

First solar cells were coated onto flexible PET-ITO-foils with efficiencies of up to 0.8 percent. To transfer these solar cells onto technical textiles, which were already covered with a silicon layer, some adaptions were necessary. The surface roughness had to be reduced further with parylene to prevent short-cuts inside the nanometer-sized layer stack. The swelling behavior of the PDMS-layer was also minimized with parylene. Due to the non-transparency of the textile, the chosen layer stack had to be inverted. Hence, the transparent electrode was deposited as a top electrode. At the left page the resulting layer stack configuration is shown which yielded a working solar cell on the technical textile.



Design of fluidic actuators of the next generation.

The goal of TOpWind: optimization of wind harvesting capability of wind turbines by means of innovative flow control concepts.
Photo: Nicholas Doherty on Unsplash

RESEARCH AND DEVELOPMENT

- **SYNTHETIC JET ACTUATORS**
- **ACTIVE FLOW CONTROL**

TECHNOLOGIES AND SYSTEMS FOR
SMART POWER AND MOBILITY

PROJECT: CLEAN SKY 2

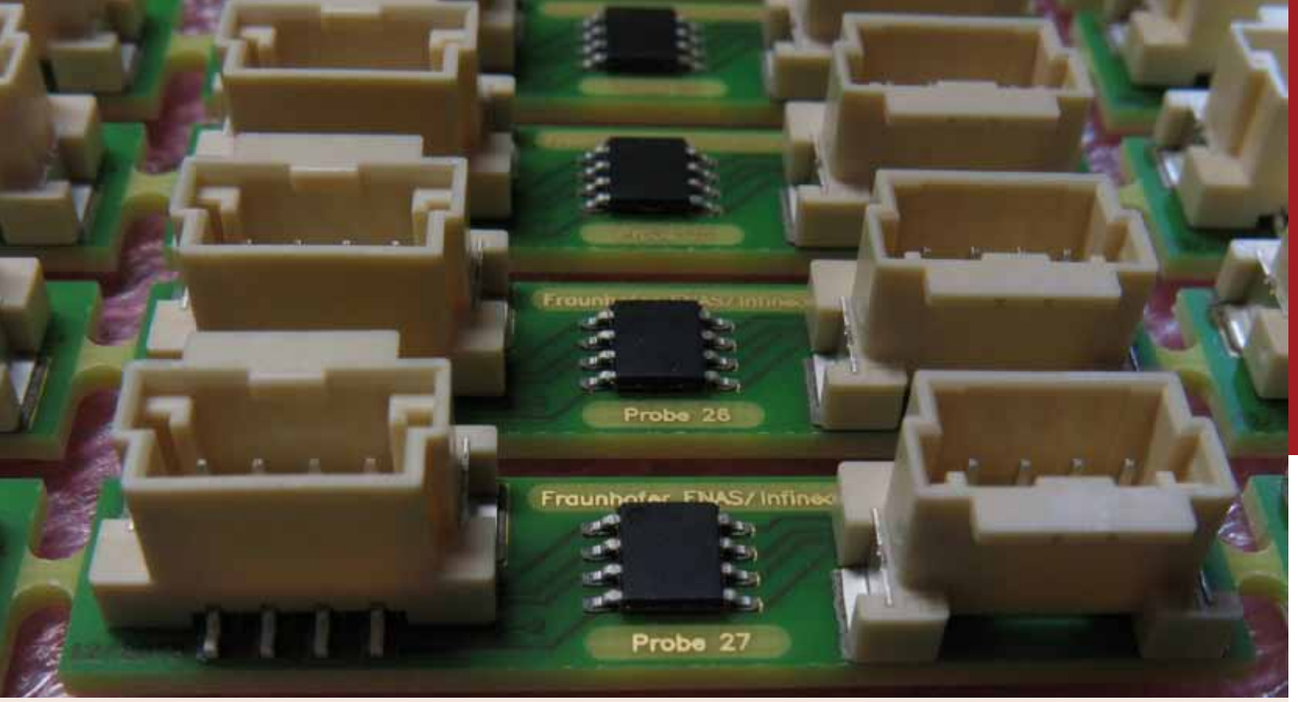
Fraunhofer is involved in one of the largest European funding initiatives CleanSky 2, in which promising technologies for the reduction of emissions and noise in the field of aviation are under investigation. Fraunhofer ENAS contributes to two main technology streams (ITDs): Airframe and Large Passenger Aircrafts.

The objective of the ITD Airframe is the development of an adjustable leading edge, the so-called Morphing Leading Edge, which contributes to increase the efficiency of the aircraft. This is achieved by an optimal adapting of the current wing geometry according to the respective flight situation (e.g. start, cruise or landing) by shifting the leading edge. Fraunhofer ENAS participates in the ITD Airframe with the development of a control and monitoring system for the actuators required for the shift of the morphing leading edge. In 2018, the preliminary design phase was completed and the detailed design and implementation phase of a demonstrator has been started.

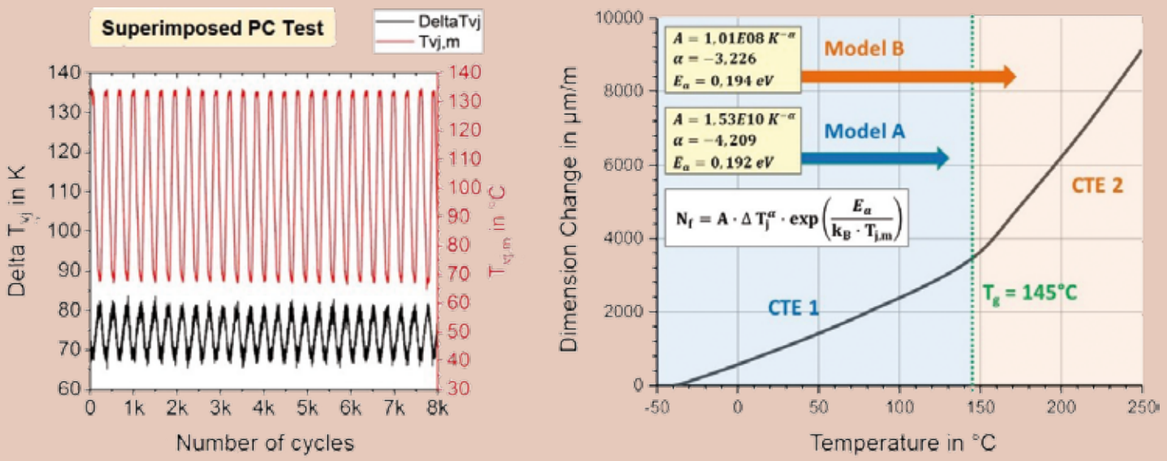
In the ITD Large Passenger Aircraft, powerful fluidic actuators are developed for active flow control, which are used in different applications. They form the basis for future optimization of the aerodynamics of an aircraft. Based on the results of the European research project AFLoNext, a new generation of actuators is being developed. Those actuators offer a significant increase in performance, robustness and reliability. The first prototypes are currently available, which will be equipped with specially developed electronics in the further course of the project and prepared for planned wind tunnel tests.

PROJECT: TOpWIND

The main goal of the collaborative project TOpWind is the development of new approaches, such as the integration of active elements, which are able to influence the flow and thus, affect the aerodynamics on rotor blades of wind turbines. In this context, the project intends to develop concepts for active flow control around the rotor blade on the basis of novel structure-integrated fluidic actuators to optimize the aerodynamic behavior. In order to develop such actuators and to validate their application on rotor blades of wind turbines, Fraunhofer participates with four institutes in the joint project TOpWind. Fraunhofer covers all areas of research which includes numerical investigation, the development of actuators and systems and finally the test of all those components. In addition, Fraunhofer manages and coordinates the overall project TOpWind. As an institute in the field of smart system integration, Fraunhofer ENAS has built up a solid expertise in the field of actuators for active flow control in projects such as CleanSky and AFloNext. In TOpWind, Fraunhofer ENAS develops flow control actuators for wind tunnel and robustness tests. Currently, first prototypes are available, which will be optimized for robustness and prepared for planned tests in the next steps of the project. The integration of those actuators in lightweight structures is a central idea in the selection of materials, as well as the implementation of a suitable actuator design.



DIL 8 (dual in line) package with implemented stress measure chip for in situ analysis of process and lifetime conditions.



Exemplary temperature curves of a superimposed power cycling test (left) and introduction of case-sensitive lifetime models (right), which are applied depending on the glass transition temperature T_g (mold compound) - Model A: $T_{vj,max} < T_g$, Model B: $T_{vj,max} \geq T_g$.

RESEARCH AND DEVELOPMENT

- **RELIABILITY**
- **AUTOMOTIVE APPLICATION**

TECHNOLOGIES AND SYSTEMS FOR
SMART POWER AND MOBILITY

STRESS MEASUREMENT TECHNOLOGY AND FE-SIMULATION FOR ADHESION TESTS IN MOLDED PACKAGES

The detection of thermo-mechanical stresses within the electronic components poses a major challenge. A classical failure of these components during the technology and product development is caused by the external stresses (temperature cycling). Based on the relationship between the external loads and failure mechanism, failure models are created (partly numerical simulation based), which can estimate the service life of these components. However, this procedure is very time-consuming and any conclusions about the intrinsic stress state cannot be withdrawn from it. Any kind of changes, for example in the geometry of the components, then require new service life tests. The implementation/substitution of the already developed stress measurement chips (CMOS technology) in electronic assemblies allows for the determination of the mechanical stresses as a function of the external load. The stress data can then be extracted during the process as well as during the operation. The focus of the current research is on the monitoring of the process chain, i.e. starting from the initial state of the chip through the packaging process till its assembly on a printed circuit board. Subsequently, information on the internal stresses under thermo-mechanical cyclic loading (as a representation of the load under operating conditions) is recorded and correlated with the occurring failure process (interfacial delamination). The investigations are accompanied with non-destructive test methods for defect analysis such as computer tomography and acoustic microscopy (Nanotom, SAM), as well as adhesion tests at package interfaces. The final aim is to develop life cycle models based on the stress values (mechanical stress or elongation) which are valid for a large number of components and thus, can reduce the number of time-consuming life cycle tests.

ACTIVE AND PASSIVE THERMAL CYCLES FOR AUTOMOTIVE APPLICATIONS

Lifetime modelling of power electronic (PE) devices and modules is an important aspect of reliability research and is typically based on power cycling tests (PCT). Thereby, the basic test principle is to actively induce power losses in the device in order to trigger realistic temperature distributions within the package. Ultimately, this will lead to the typical failures, such as die-attach degradation or failures in the chip top side connection. In the frame of an extensive study, different PCT profiles were applied in order to investigate the dependency of different load factors on the lifetime of various discrete power electronics devices, such as junction temperature swing, absolute temperature level or heating time. An adapted version of the well-known LESIT equation, which includes a Coffin-Manson related term and an Arrhenius term, was used for fitting the experimental test data. Although the derived model showed a very good agreement with the test data, it was not able to predict the test results of additionally performed PCT that were superimposed with passive thermal cycles. Those tests provide an even better representation of the actual service conditions than the standard tests. A more in-depth analysis revealed that an explanation could be found in the influence of the mold compound, more precisely in its glass transition temperature T_g. I.e., the modelling had to be divided into two groups: one including only test cases with applied test temperatures below T_g, and the other one including test cases with temperatures exceeding T_g. Using this grouping, it was finally possible to predict the lifetime of the superimposed test results much better.

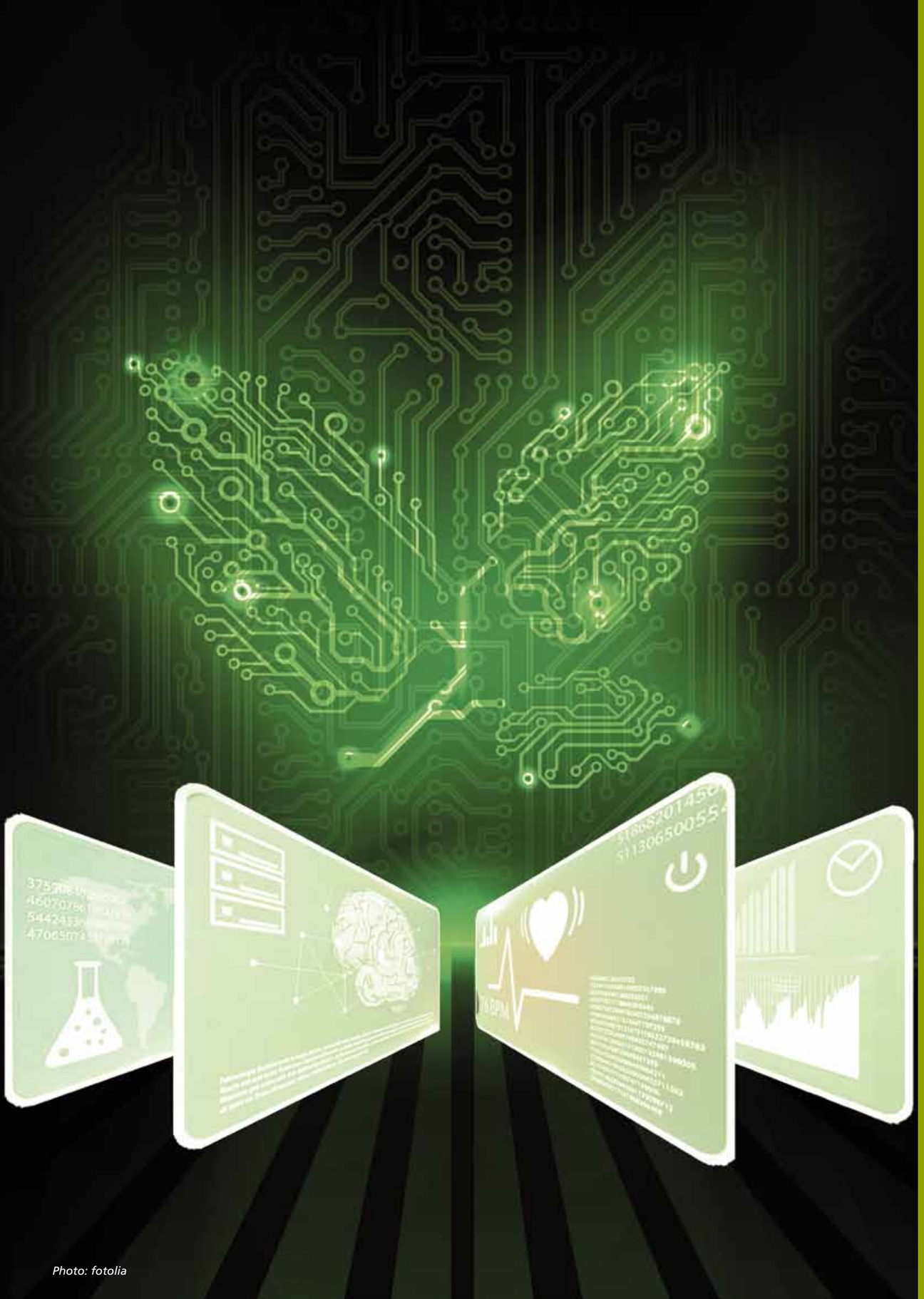


Photo: fotolia

TECHNOLOGIES AND SYSTEMS FOR SMART HEALTH

The business unit Technologies and Systems for Smart Health combines R&D activities with applications in the field of health and life sciences. Our research is focused on the technical and technological aspects, especially in using micro and nanotechnologies for applications in the service of medical science, biology, and healthy living.

Our research projects include, among others, developments for miniaturized sensor and actuator systems including system integration and biocompatible encapsulation for medical implants. The main motivation for implantable sensors and actuators is the replacement, restoration and improvement of human senses and organs.

In addition, integrated sensors and actuators can also be utilized in surgical tools and smart medical devices for the monitoring of patients. Main research activities are biocompatible materials, especially for the interface between biological tissue and technical devices as well as the utilization of MRI-compatible materials and wireless data and energy transfer.

The field of measurement and analytical technologies combines all developments for diagnostic test systems using microfluidic and/or spectroscopic components. Goal of the development is the miniaturization and automation of established analytical procedures into portable systems as well as the development of novel systems and components based on micro and nano technologies.

BUSINESS UNIT MANAGER

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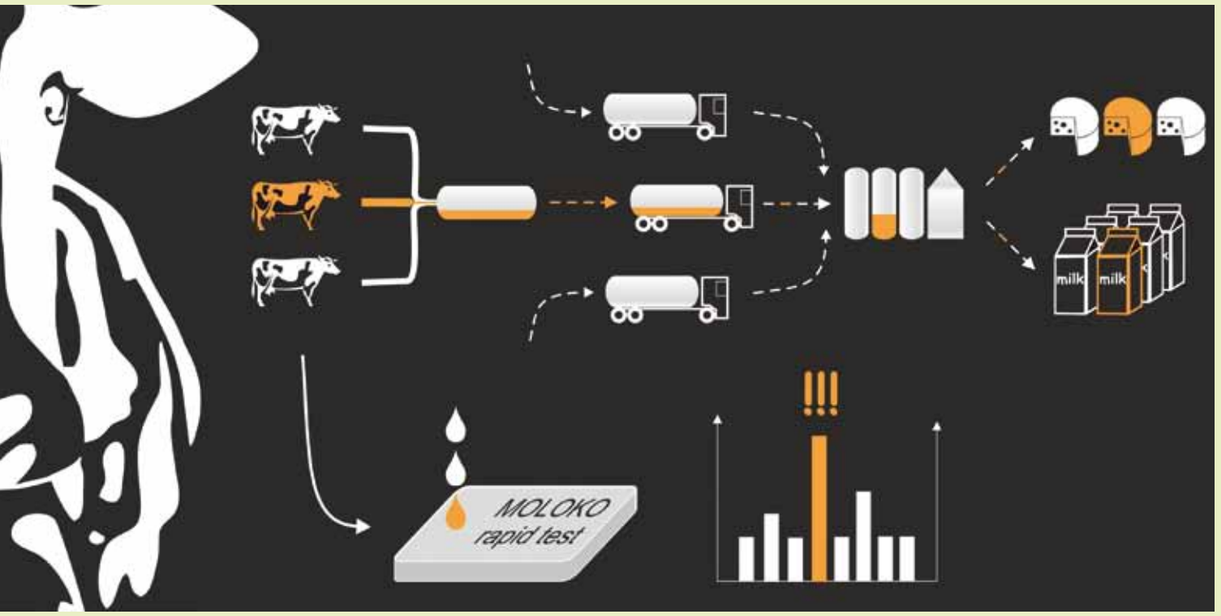
Piezoelectric micro sensors for industrial applications – Presentation of a German – Canadian cooperation by the German Federal Minister for Economic Affairs and Energy Peter Altmaier.



A novel test system for rapid and onsite analysis of food quality and safety parameters of milk are developed within the project MOLOKO.

RESEARCH AND DEVELOPMENT

- PIEZOELECTRIC MICROSYSTEMS FOR OCT
- RAPID FOOD TEST

TECHNOLOGIES AND SYSTEMS FOR SMART HEALTH

PIEZOELECTRIC MICRO SENSORS FOR OCT APPLICATIONS

Fraunhofer ENAS develops piezoelectric micro systems with Aluminumnitrid (AlN). This piezoelectric transducer has high interest in industry as sensor and actuator material. To realize these industrial applications a consortium, including Fraunhofer ENAS (competence: piezoelectric micro systems), the Canadian company Preciseley Microtechnology Inc. (competence: electrostatic micro systems) and EDC Electronic Design Chemnitz GmbH (competence: ASIC development) overcame two technical challenges within the project. On the one hand, the piezoelectric transducer processes were successfully integrated into the high volume production of the Canadian partner. On the other hand, the ASIC showed a fast, precise and low-noise measurement of the piezoelectric sensor signal. This development enable e.g. a miniaturization of highly precise endoscopic systems for OCT (optical coherence tomography). The consortium showed a technical path using OCT not only for ex vivo applications (e.g. in ophthalmology) but also for endoscopic based non-destructive in vivo applications.

The new development was funded by the BMWi (Federal Ministry for Economic Affairs and Energy) and the EDT (Economic Development and Trade) as part of the SME Innovation Programm (ZIM). A project demonstrator as example for the latest technical innovation in micro technology and micro systems was presented to Peter Altmaier, the German Federal Minister for Economic Affairs and Energy, during the SME innovation day of the AiF (Arbeitsgemeinschaft industrieller Forschungsvereinigungen).

PROJECT: MOLOKO – NOVEL RAPID TESTS FOR FOOD QUALITY AND ANIMAL HEALTH

Having complex global food supply chains, the consumer needs to trust in the quality and safety of the products. Recent chases of food fraud (for example the mislabelling of low quality products as high quality ones) or food safety issue (spread of toxins along the food chain) showed the vulnerability of the food chain. Although analysis procedures for many food quality and safety parameters exist, they are not used by default because they require intensive laboratory equipment and skilled personnel. In the H2020 Project MOLOKO (GA No 780839), a novel plasmonic sensor and test system are developed in order to enable rapid and onsite analysis of food quality and safety parameters of milk. The consortium consists of research institutions and companies, including dairy companies, from seven European countries.

In the project, Fraunhofer ENAS is developing the microfluidic chip around the plasmonic sensor. For the analysis, a sample is automatically withdrawn from the milk pipeline. The system will then perform a sample preparation of the milk sample, including pre-filtration and dilution. The sensor enables a six-time multiplex analysis including calibration with subsequent regeneration of the sensor surface. Besides the information gained of the milk itself, the parameters also allow conclusions with respect to the health and performance of each cow individually. On the long term goal, these data might also be used for successful breeding of cows with favourable milk parameters.

Further information can be found at www.moloko-project.eu

In the project »Microfluidic Based Detection of Microbial Communities and Antibiotic Responses in the Management of Diabetic Foot Ulcers« (MIDARDI), a team of Indian experts from the Manipal University, Achira Labs and German experts from BiFlow Systems GmbH, Fraunhofer IZI-BB and Fraunhofer ENAS are working together.

Fraunhofer ENAS cooperates within the project »bioElektron – Biodegradable Electronics for Active Implants« funded by the Fraunhofer-Gesellschaft and develops bio-degradable printed passive and active microelectronic components.

RESEARCH AND DEVELOPMENT

- **POINT-OF-CARE TEST**
- **BIODEGRADABLE PRINTED COMPONENTS**

TECHNOLOGIES AND SYSTEMS FOR
SMART HEALTH

PROJECT: MIDARDI – FOR A BETTER TREATMENT OF DIABETIC FOOT ULCER

Microfluidic sample handling and tailored biotechnology are the key technologies for rapid and reliable pathogen detection at the point of care. Although test strip based detection of single pathogens is already available on the market, the technology is not suited for the analysis of complex pathogen populations such as wound fluids. In the project »Microfluidic Based Detection of Microbial Communities and Antibiotic Responses in the Management of Diabetic Foot Ulcers« (MIDARDI), Fraunhofer ENAS joined a team of German (Fraunhofer IZI-BB, BiFlow Systems GmbH) and Indian (Manipal University, Achira Labs) experts. The goal of the project is a point of care test for pathogenic species in wounds and the analysis of their antibiotic resistance, in order to start the targeted treatment rapidly. Fraunhofer ENAS` main focus lies on the microfluidic sample preparation including DNA amplification, DNA digestion and DNA hybridization.

Background of the project is the steadily increasing numbers of obesity and type 2 diabetes in India and Europe. Increased insensibility comes along with neuropathy as a symptom of the target diseases. The patients often develop wounds with distorted healing at their feet, which need immediate treatment. Since traditional analysis methods can take several days, there is a strong need for a rapid test. Such a tool not only needs to be fast but needs to show the dominant pathogen cultures as wells as their antibiotic resistance profile.

The consortium is funded by the BMBF and the Indo-German Science and Technology Centre (IGSTC).

MAVO BIOELEKTRON

Surgeries are always a severe intrusion into the human body. In some cases there are at least two required: The first one to implement an electrode for interaction and the second one to remove it after use. Based on this scenario it would be handy if all material that is needed remains in the body and is degenerated. For this use case, the Fraunhofer Institutes ENAS, IBMT, ISC and IWKS, led by Fraunhofer FEP, choose, develop and evaluate a suitable set of materials for their application as electrodes, which work for a defined period of time before they are bio-absorbed in the body. Furthermore, also an in situ amplification of signals is under consideration, employing transistors built of zinc or polymeric materials that are also degraded by the body after its use.

At Fraunhofer ENAS, all bio-degradable printed passive and active microelectronic components were deposited using inkjet and aerosol jet technology with adapted post treatment technologies in order to acquire future solutions for medical implants. The aim of these printed electronic implants is to generate stimulation or impulse within a human body, to unleash certain hindered actions. The implementation of digital manufacturing tools such as inkjet and aerosol jet technology endorses tunable and precise deposition of bio-degradable functional materials such as conductors, dielectrics and semiconductors for building devices with predictable performance. Hereby, synergies within digital fabrication are used by exploiting complementary printing capabilities of different printing technologies in order to compensate rheologic differences within used ink systems formed by particle size distribution or viscosity within the printing process itself.

Photo: RF123 (Oliver Sved)

TECHNOLOGIES AND SYSTEMS FOR SMART PRODUCTION

The business unit Technologies and Systems for Smart Production addresses topics of the automation and digitization of production. The focus is on the provision of technologies for the individualization of products and sensor-based monitoring of production.

Digital production processes such as inkjet and aerosol jet printing processes enable resource-efficient mass production of intelligent and individualized products down to batch size 1. The necessary smart production environments are supported by our own sensor solutions. These include, in particular, sensor solutions, which monitor machine conditions and processes during production. Thus, e.g. in addition to the implementation of the plug and play functionality for the exchange of sensors in production environments, new sensor systems for harsh environments or for monitoring production resources such as greases and oils or for monitoring air quality will be developed.

BUSINESS UNIT MANAGER

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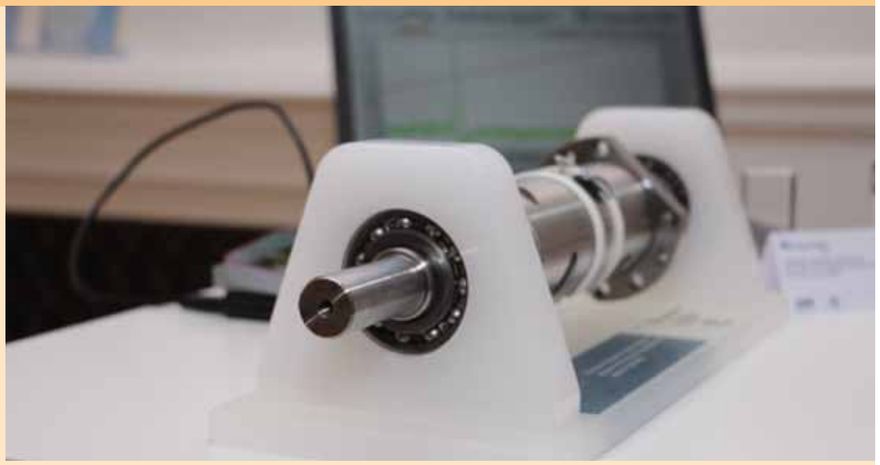
Fabrication of functional layers by means of a 6-axis-robot-assisted inkjet printing technology for the manufacturing of cable harnesses on car parts.

Integrated sensor system for precise ball screw monitoring of temperature and force.



Ball screw drive with integrated sensor system.

RESEARCH AND DEVELOPMENT

- CUSTOMIZED PRODUCTION OF SERIAL PARTS
- SENSORS AND ACTUATORS IN MECHANICAL ENGINEERING

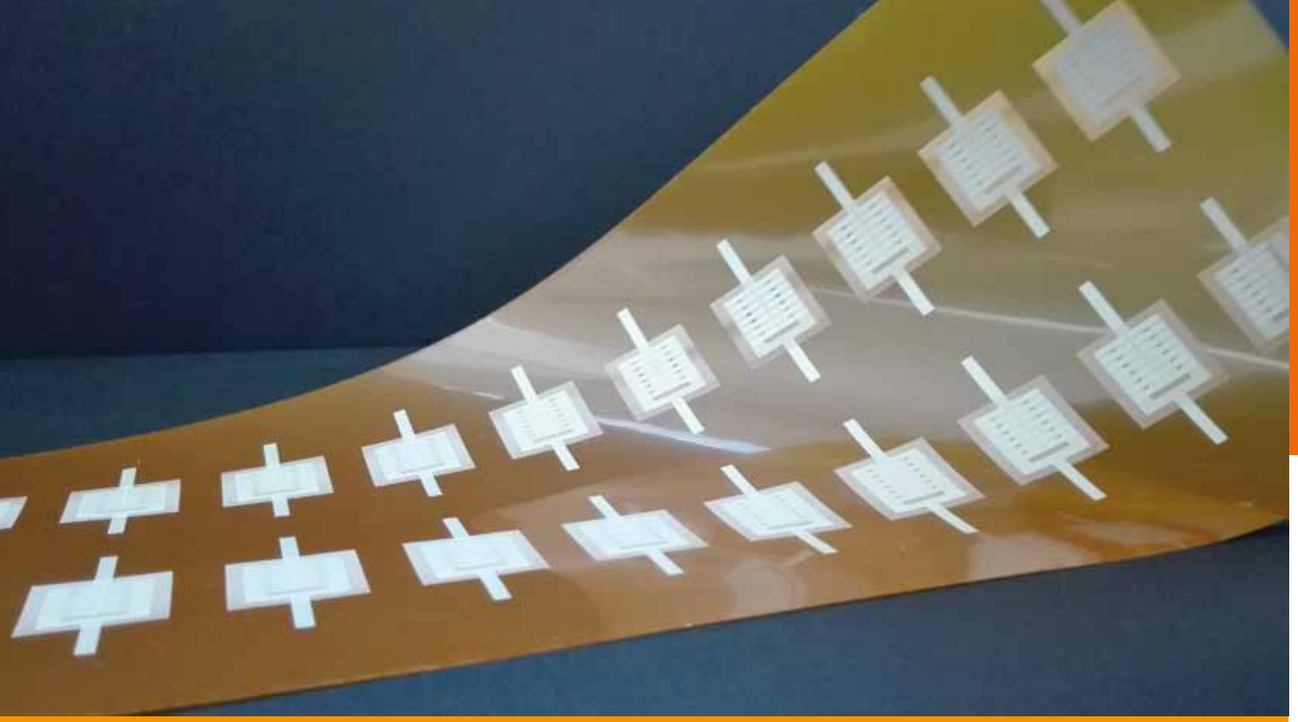
TECHNOLOGIES AND SYSTEMS FOR SMART PRODUCTION

DIGITAL MANUFACTURING IN MASS PRODUCTION – FUNCTIONAL PRINTING ON 3D OBJECTS

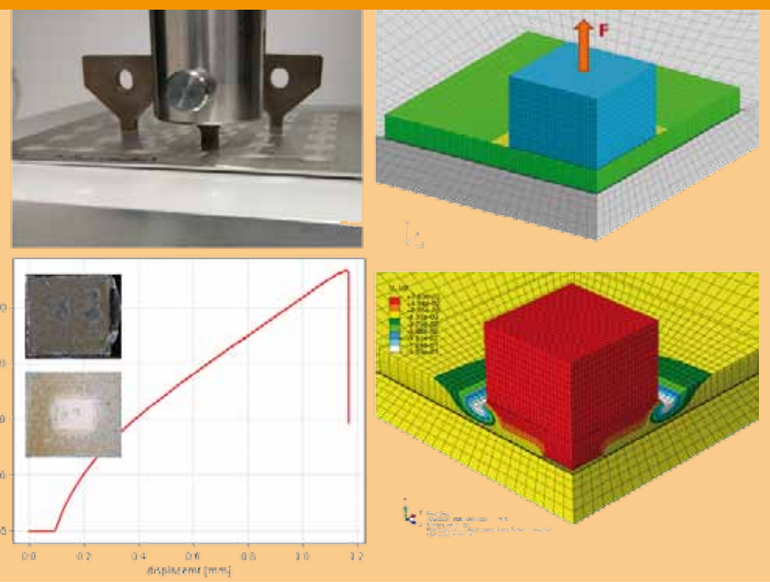
The automated manufacturing of customized products has been targeted by various markets (e.g. automotive, aerospace, lighting, etc.) and manufacturing industries, respectively, for years. Notwithstanding, the demand for technologies allowing to efficiently manufacture individual items under mass production conditions has not yet been met. By employing printing technologies (inkjet print and dispense) Fraunhofer ENAS, in cooperation with partner institutes, has established processes, which allow the product to be digitally customized during standard production. One speaks of functional printing on 3D objects, precisely. For this purpose, functional inks with dielectric or electrically conductible properties are applied to print cable harnesses or even complex sensor systems on arbitrary 3D objects. The printing on 3D objects is implemented in a robot-assisted process, allowing an application of the printing technology on most diverse and distinctive objects. The upper figure on the left page shows exemplarily the fabrication of functional layers by means of a 6-axis-robot-assisted inkjet printing technology for the manufacturing of cable harnesses on car parts. Fraunhofer ENAS successfully conducted extensive research to overcome the challenges (e.g. adhesive strength of printed layers and realization of homogenous electrical conductors on curved or vertical surfaces) of functional printing on 3D objects. The targeted selection and adaptation of material and printing parameters proved to be the key to success.

STRUCTURE-INTEGRATED WIRELESS SENSOR AND ACTUATOR TECHNOLOGY FOR MANUFACTURING SYSTEMS (SDSEMA)

The fourth industrial revolution is changing Germany as a business location. Product development, production, logistics and customers are networked. The result is an intelligent, adaptable, efficient and sustainable production that can respond to market changes in the shortest possible time. A significant component of this development are sensor-based production resources. For inherent control functions, numerous sensors detect utilization in real time, as well as operating and maintening conditions of essential machine components. Evaluated sensor data are communicated wirelessly to higher-level planning and control systems. In the project SdSeMa of the High-Performance Center »Functional Integration for Micro- and Nanoelectronics«, the Fraunhofer Institutes ENAS, IIS/EAS, IPMS, and IZM/ASSID, with assistance of Fraunhofer IWU and Fraunhofer IKTS, worked on new technologies for the structural integration of sensors and actuators in machine components. The results were demonstrated on the example of a ball screw drive. The challenge was to measure the parameters that are important for manufacturing systems, such as force, temperature, acceleration and vibration, for maximum accuracy right at the point of origin. Therefore, miniaturized sensor systems have been developed, which together with networked and energy-efficient information processing components can be integrated into a wide variety of machine components. Current communication technologies are used for wireless data transmission to IoT gateways. The developed technologies are characterized by excellent integration capability and can be used in many applications.



Screenprinted composite humidity sensors.



Experimental and simulative evaluation of printed interfaces using pull tests.

RESEARCH AND DEVELOPMENT

- SENSOR SYSTEMS FOR CONDITION MONITORING
- RELIABILITY OF PRINTED SMART OBJECTS

TECHNOLOGIES AND SYSTEMS FOR

SMART PRODUCTION

PRINTED HIGHLY-SENSITIVE COMPOSITE HUMIDITY SENSORS

Against the background of digitization, smart living and industry 4.0 there is a great need for universally applicable and cost-effective sensors. This also applies to humidity sensors. Here, the range of application covers for example the measurement of relative humidity in buildings and production halls, detection of (condensation) water in packages and condition monitoring of lightweight materials.

Nano or microcomposite-based moisture sensors combine the advantages of polymers and ceramics, such as ease of manufacture and high sensitivity, thus providing an excellent basis for a wide variety of applications.

At Fraunhofer ENAS, such composite moisture sensors were fabricated completely with screen printing technologies in various layouts and with active areas in the size range from one to 50 cm^2 on flexible substrates (e.g. polyimide, PET) and comprehensively characterized. The moisture-sensitive dielectric of the capacitive sensors consists of ceramic particles, which are partly embedded in a polymer binder. The sensors show a capacity change of more than 100 percent according to a change in relative humidity from 20 to 80 percent r. h. as well as a sensitivity of up to 125 pF / percent r. h. As part of the sensors general built up, the screen printed electrodes are based on silver-containing pastes that gain conductivity after thermal post-treatment. In cooperation with the Chemnitz University of Technology in the framework of the Cluster of Excellence »MERGE«, composite moisture sensors were also integrated into glass fiber reinforced thermoplastics. With these sensors, a water absorption of the laminates of less than 0.5 percent by mass can be reliably detected.

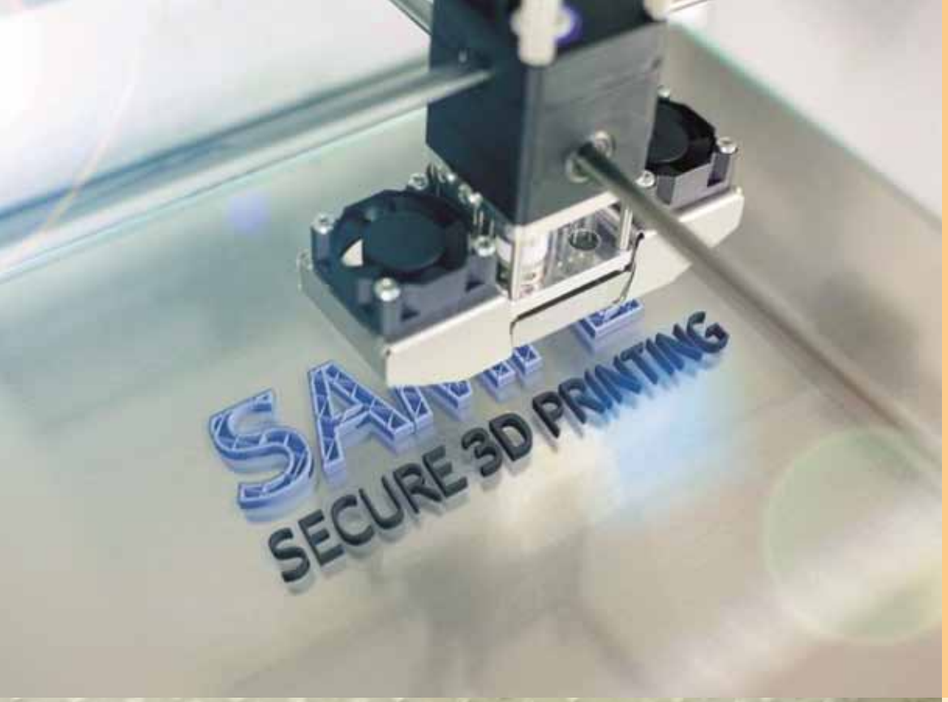
THERMO-MECHANICAL RELIABILITY ASPECTS OF PRINTED FUNCTIONALITIES

Printed functionalities are new »Printed Smart Objects« generated by traditional and digital printing technologies, such as sensors, antennas or batteries, and are increasingly being integrated into classic design components and technologies. This automatically brings with it the transmission of their reliability requirements to these new technologies.

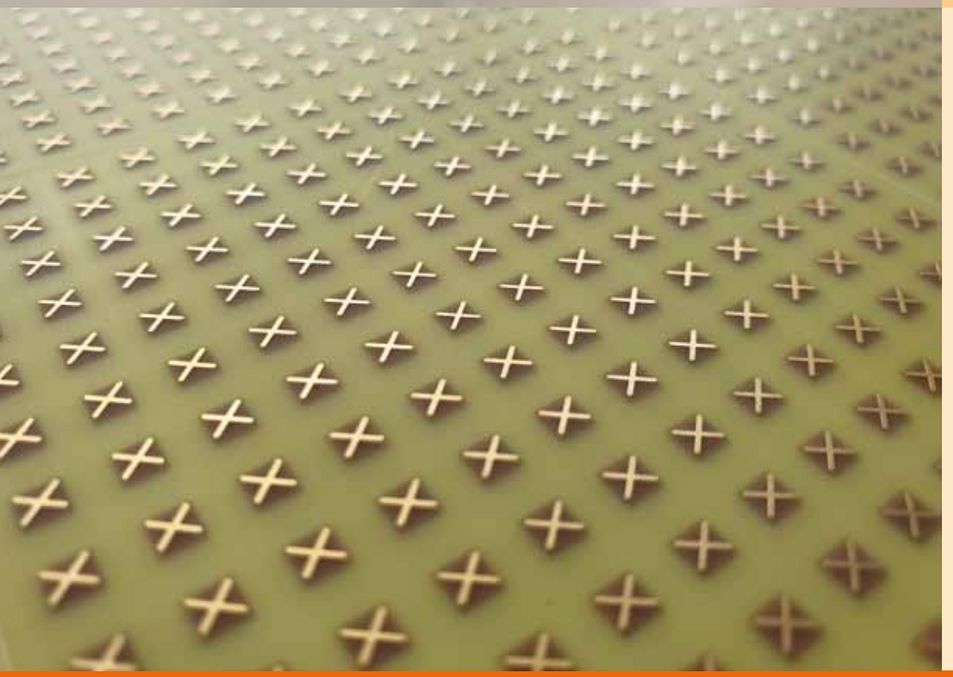
In the Fraunhofer lighthouse project »Go Beyond 4.0«, which is headed by Fraunhofer ENAS, the necessary technologies are being researched, with the department Micro Materials Center being responsible for the reliability aspects. The aim is to establish a generally valid reliability concept for these new technologies, which is why this work accompanies the technology development as early as possible.

The work focuses on the analysis of potential failure causes, failure types and failure consequences for weak point identification and for the Physics of Failure-based assessment of reliability risks. Both process and operational reliability are taken into account.

Fraunhofer ENAS focuses primarily on the behavior of the printed materials used and their integration. For this purpose, a combined experimental-simulative methodology is used, which is adapted to the special requirements of the technologies. Special challenges are the necessary determination of material data and the evaluation of the interface behavior, especially the adhesion. For this purpose, novel analytical methods are developed and extensive tests are carried out.



Security solutions for the entire process chain of 3D printing are developed within the project SAMPL.
Photo: PROSTEP AG



Implementation of a sensor metamaterial by an array of electromagnetic resonators with subwavelength dimensions.

RESEARCH AND DEVELOPMENT

- SECURED SOLUTION FOR ADDITIVE MANUFACTURING
- NEW SENSOR MATERIALS FOR LIGHTWEIGHT STRUCTURAL ENGINEERING

TECHNOLOGIES AND SYSTEMS FOR

SMART PRODUCTION

PROJECT: SAMPL

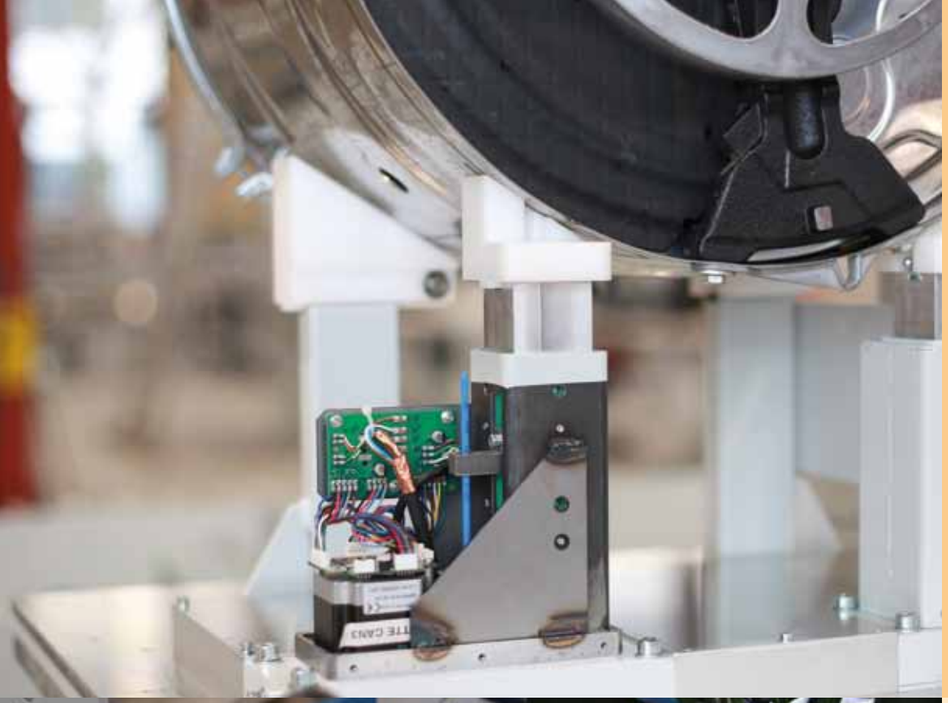
The objective of the SAMPL (Secure Additive Manufacturing Platform) project is the development of a completely secured solution for additive manufacturing processes. Within this project, particular attention is paid to the entire process chain of 3D printing. This chain includes the creation of the print data, the subsequent transfer of the print data to a 3D printing service provider, the printing on trusted 3D printers secured by secure elements as well as the unambiguous identifiability of the print object and the assignment to the used printing license. The solution developed in SAMPL makes it possible to prove the origin of printed components and to verify their authenticity.
For this purpose, well-established encryption technologies are employed. A blockchain technology based digital license management system is added to enhance the security. Both encryption technologies and license management system are integrated into the data exchange solution OpenDXM GlobalX. The blockchain technology, which gained prominence primarily through cryptocurrencies, is used to prove the authenticity of transactions and in this context for the licensing for printing components. The Industry 4.0 Standard OPC-UA is used as interface for the exchange of certification and license data between legal owner and print service providers.
The aim of Fraunhofer ENAS is, to develop a connection system to connect 3D printer, used in additive manufacturing, with the Secure Additive Manufacturing Platform via the OPC-UA standard protocol and to further integrate them into the overall system.

This project is funded by the Federal Ministry of Economic Affairs and Energy (BMWi) within the Technology Program Framework PAiCE (Platforms, Additive Manufacturing, Imaging, Communication and Engineering).

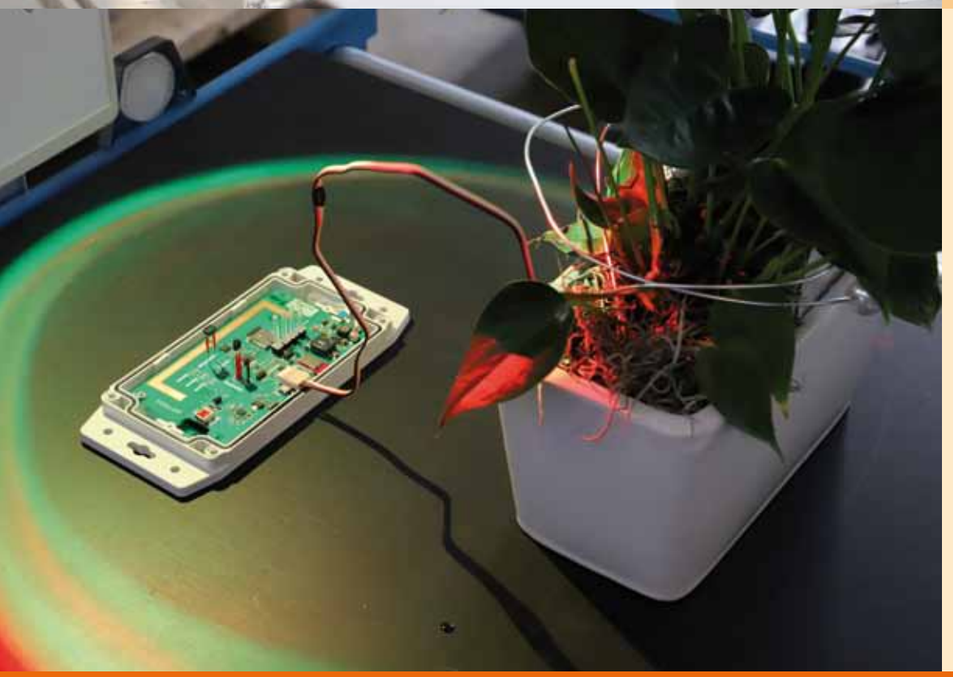
IMPLEMENTATION OF ZERO-POWER SENSORS WITH SENSORY METAMATERIALS FOR APPLICATIONS IN LIGHTWEIGHT STRUCTURAL ENGINEERING

Due to their structure, metamaterials show a strong frequency filter behavior, which changes with material changes. This circumstance is used to implement a passive sensor function, so that passive structure and condition monitoring of lightweight structures becomes possible.
For this purpose, metamaterials and their application as zero-power sensors for use in lightweight structures were being investigated within the framework of the Federal Excellence Cluster MERGE »Technologies for Multifunctional Lightweight Structures« of Chemnitz University of Technology in close cooperation with the Fraunhofer ENAS.
The approach pursued here to realize a passive and material-immanent sensor function for lightweight structures uses regularly arranged electromagnetic resonators with sub-wavelength dimensions and their integration into lightweight structures. Due to the strong frequency filter behavior of the resonator arrays, a specific frequency response can be generated. Changes in material or structure influence the frequency filter behavior, which is reflected in the displacement of significant resonance points.
By means of electromagnetic waves in connection with a transmission or reflection measurement, the changes in the frequency behavior can be determined and conclusions can be drawn about the presence of a structural or material change.

The work was carried out within the framework of the Federal Excellence Cluster EXC 1075 »MERGE – Technologies for Multifunctional Lightweight Structures« and funded by the German Research Foundation (DFG). The financial support was gratefully acknowledged.



The workpiece carrier adapts itself to the individual product characteristics.
Photo: David Gense, Fraunhofer IEM



Light measurment by the smart sensor system exemplified for plant production.

RESEARCH AND DEVELOPMENT

- SMART ACTIVE WORKPIECE CARRIER
- WIRELESS SENSOR SYSTEM

TECHNOLOGIES AND SYSTEMS FOR SMART PRODUCTION

ACTIVE WORKPIECE CARRIER

The demand for flexible solutions, when manufacturing a wide variety of products in small quantities, is growing in plant and conveyor technologies. Often, each product variant requires its own adapted workpiece carrier. Depending on the number of different products, this results in increased storage space requirements. In addition, there are long changeover times in production when changing products or variants. In close cooperation with the University of Paderborn, a wireless technology was developed which enables a workpiece carrier to adapt itself mechanically and logically to the next product variant within the production cycle time. Therefore, it is necessary to integrate logic, sensors and actuators on the workpiece carrier. It was developed an autonomous and powerful power supply that can be charged wirelessly within short time cycles. For this purpose, a smart battery system was investigated together with a smart charger. This overall system is able to provide different voltage levels for the different active components. In order to save energy, the system has I/O interfaces to supply the various components with energy when it is needed. This makes it possible to use a smaller and less expensive battery. In addition, the smart charger is connected to a Wi-Fi interface in order to communicate with the higher-level production control system. This enables the transmission of important battery parameters, allowing the battery condition to be monitored and the remaining service lifetime to be estimated and optimized.

WIRELESS SENSOR SYSTEMS FOR FLEXIBLE DESIGN OF PRODUCTION PROCESSES

The goal of the BMBF project »DiSSproSiP« was the automation and individualization of industrial production systems in the form of a wireless, intelligent sensor system. For this purpose, a product should be able to control its own production process with the help of an RFID-based sensor platform. Therefore, a sensor module and a read/write station were developed in the project. The read/write station can be installed at any position in the plant and connected via an industrial bus such as OPC-UA or Profinet. Production and sensor data are then transferred from the sensor module to the system via the read/write station. Together with project partners, Fraunhofer ENAS has developed a proprietary protocol for RFID transmission. With the system developed in the project, production plants can be set up decentrally, since they can adapt the local production step depending on the sensor data and production history stored on the product itself, without having to obtain data from a central institution. In order to supply the RFID module with energy, a wirelesse power transmission channel was added to data communication channel. Special requirements were the environmental conditions, such as little available space and metal in the vicinity of the transmission antennas.
The project was successfully completed by implementing prototypes of the developed hardware in three different scenarios. In one scenario, the developed technology was already tested during ongoing operation of a large washing machine manufacturer.

photo: pixabay

HIGHLIGHTS

DISSERTATIONS

October 5, 2018

PhD:	John Brückner
Topic:	Elastizitätsmodul und Bruchfestigkeit von Poly-Silizium-Membranen kommerzieller MEMS-Mikrophone
Institution:	Chemnitz University of Technology

October 25, 2018

PhD:	Christian Helke
Topic:	Herstellung von neuartigen Reflektorsystemen und Erarbeitung einer systembezogenen Integrationstechnologie für VIS und IR Fabry-Pérot Interferometer
Institution:	Chemnitz University of Technology

AWARDS AND ACHIEVEMENTS

Two awards for young scientist

Silvia Hertel, a young PhD student at Fraunhofer ENAS, received two awards in 2018. At first, she received the Best Paper Award for her oral presentation »Electrochemical Deposition for the Circuit Board« at the conference »EBL 2018 – Electronic Components and Circuit Boards 2018« in Stuttgart-Fellbach in February 2018.

Silvia Hertel received the Heinz-Leuze Prize from Galvanotechnik Volume 108 in 2017 for her publication titled »Electrochemical Deposition of Alumina and Palladium from Ionic Liquids for Reactive Wafer Bonding«. In 1985, German Association for Electroplating and Surface Technology (DGO) and the Leuze family from Saulgau, Germany, jointly donated the Heinz-Leuze Prize in recognition and acknowledgement of his service for the further development of electroplating, especially in the journalistic field. The Prize is awarded annually for a technical-scientific publication of the previous year in a German Journal, which features a clear and didactic presentation of an important technical-scientific issue.

Prof. Dr. Klaus-Dieter Lang, Director of the Fraunhofer IZM, handed over the Best Paper Award to Silvia Hertel from Fraunhofer ENAS at the Fachtagung EBL 2018 – Elektronische Baugruppen und Leiterplatten 2018. Photo: DVS

AWARDS AND ACHIEVEMENTS

Best Paper Award at InterPACK 2018 in San Francisco, USA

Alexander Otto received the Best Paper Award for his oral presentation »Investigation of active power cycling combined with passive thermal cycles on discrete power electronic devices for automotive application« at the »International Technical Conference on Packaging and Integration of Electronic and Photonic Microsystems 2018« in San Francisco, California, USA.

Fraunhofer ENAS Research Award

Dr. Lutz Hofmann received the Fraunhofer ENAS Research Award 2018 during the 10th anniversary event of Fraunhofer ENAS in October 2018. The scientist and engineer from Chemnitz investigates technologies that are required for three-dimensional integration (3D integration) into micro-electromechanical systems (MEMS). With the help of these integration technologies, MEMS can be integrated into modules and systems that exhibit a high degree of miniaturization or particularly thin form factors.

With his work, Lutz Hofmann has helped Fraunhofer ENAS in Chemnitz to achieve expert status in the special research field of through silicon vias (TSV) for microsystems. The renowned market analyst Yole Développement lists the Chemnitz Institute as one of three European research institutes in this field, alongside the notable French research institute CEA-Leti and the Belgian IMEC, and as one of only six worldwide.

With his dissertation »3D-Wafer Level Packaging approaches for MEMS by using Cu-based High Aspect Ratio Through Silicon Vias« Dr. Hofmann received his doctorate in 2017 at Chemnitz University of Technology. In 2015, he already received an award for the best conference publication with a publication on the topic of 3D integration at the »International Wafer Level Packaging Conference (IWLPC)« in San José, USA.

The awardee of the Fraunhofer ENAS Research Award 2018, Dr. Lutz Hofmann (middle) with the acting director of the Fraunhofer ENAS, Prof. Dr. Thomas Otto (2. from right), the chair women of the Research Award committee, Prof. Dr. Karla Hiller (2 from left) as well as the laudator Dr. Roy Knechtel (left) from X-FAB Semiconductor Foundries AG and Prof. Dr. Stefan E. Schulz (right), head of the department Back-End of Line and deputy director of the Fraunhofer ENAS.
Photo: Ines Escherich

CONFERENCES AND WORKSHOPS

International conferences, seminars and workshops

The 12th Smart Systems Integration Conference and Exhibition took place on April 11 – 12, 2018, in Dresden, Germany. 312 experts from 22 countries discussed the latest developments in the fields of system integration and packaging, design of smart integrated systems and smart systems applications. Besides software issues, the topic of connectivity was addressed for the first time in order to develop a common understanding for the questions to be solved. Furthermore, for the first time the activities of the Smart Systems HUB were embedded in both the pre-field trip in Dresden and the after-conference trip to Chemnitz.

The year 2018 was marked by the 10th anniversary of Fraunhofer ENAS. On October 17, 2018, German and foreign guests from politics, industry and science accepted our invitation to come to Chemnitz. During the festive event, the Saxon Minister President Michael Kretschmer, the President of the Fraunhofer-Gesellschaft Prof. Reimund Neugebauer, the Mayor of Chemnitz Barbara Ludwig and the President of Chemnitz University of Technology Prof. Gerd Strohmeier acknowledged the positive development of the institute. During the scientific colloquium, speakers included representatives from GLOBALFOUNDRIES, Infineon Technologies Dresden, T-Systems Multimedia Solutions and Chemnitz University of Technology, presented the latest developments and future trends. The festive event was completed by an exhibit called »Retrospective« with contributions from 17 exhibitions of »Science meets Art« (Fraunhofer ENAS), »EigenArt« (artistic contributions by employees from Fraunhofer ENAS, Center of Microtechnologies of Chemnitz University of Technology, Fraunhofer IWU and in cooperation with the Fraunhofer network »Science, Art and Design«) and the »Smart>SOS« Vertigo project (EU program STARTS – artistic representation of the EU project Bio4Comp). Furthermore, the research award of Fraunhofer was presented during the evening reception.

Prof. Dr. Reimund Neugebauer (President of the Fraunhofer-Gesellschaft) (right), Michael Kretschmer (Prime Minister of the Free State of Saxony) (2nd from left), Barbara Ludwig (Mayor of the City of Chemnitz) and Prof. Dr. Gerd Strohmeier (Rector of the Chemnitz University of Technology) (left) and Prof. Dr. Thomas Otto (acting director of Fraunhofer ENAS) (2nd from right) opend the celebration of th 10th anniversary of Fraunhofer ENAS.
Photo: Ines Escherich

During the festive event the »SMART>SOS« – VERTIGO project within the STARTS program of EU was introduced. The conceptional artist Dr. Tim Otto Roth works together with scientists form Dresden and Chemnitz in Germany as well as Lund and Kalmar in Sweden, to transfer the scientific content of the EU project Bio-4Comp into an artwork
Photo: Ines Escherich

CONFERENCES AND WORKSHOPS

The digital signal box on the railway test area in Annaberg-Buchholtz was explained to the participants of the Smart Rail Connectivity-Campus workshop on September 6, 2018.

The Chemnitz workshop series on nanotechnology, nanomaterials and nanoreliability successfully continued in 2018. The department System Packaging invited researchers to a workshop on June 12 – 13, 2018. The seminar addressed the latest research results on the subject of »Materials and Technologies for Packaging«. The series continued with the workshop »Nanomaterial Integration for Electronics and Sensors – Ready for Industrial Applications«. The seminar, hosted by the department Back-end of Line, took place during the »Microsystems Technology, Micromechanics and Microelectronics« symposium on October 24, 2018, in Chemnitz and focused on graphene and carbon nanotubes and their potential for various applications such as infrared sensors, electronics and energy storage. The last seminar of 2018 focused on the topic »Reliability and Functional Safety of Electronic Components and Systems«, which was hosted by the department Micro Materials Center on November 14, 2018.

On September 6, 2018, Fraunhofer ENAS conducted the workshop »Sensors for Rail Vehicles and Monitoring of Track Systems and Trains« as part of the activities of the Smart Rail Connectivity-Campus, an initiative for innovation in rural areas. More than 70 experts followed our invitation to Chemnitz. Furthermore, the experts were able participate in a demonstration of the digital positioner in Annaberg-Buchholz South and could ride with the Thales test train, which is equipped with sensors for object recognition, on the test track. The Smart Rail Connectivity-Campus in Annaberg-Buchholz comprises the expertise of Chemnitz University of Technology, the Deutsche Bahn and the region of Annaberg as well as companies and research institutions. The region will become the leading location for European research, prototyping and test for interconnected and automated mobility in the years to come. The thematic priority of the campus lies on automated driving, smart and connected systems for rail traffic, railway technology and hybridization.

The High-Performance Center »Smart Production« invited guests to the first workshop »SMARTPRO« on October 15, 2018, at the Fraunhofer Institute for Machine Tools and Forming Technology IWU. The focus of the workshop lay on the activities of the partners of the High-Performance Center as well as on research areas of Fraunhofer ENAS such as reliability of organic composites and material compounds with embedded electronics, and micro and nanocomposites for sensory purposes.

On December 3 and 4, 2018, the »MINAPIM – Micro and Nanotechnology and Photonics Interconnection for the Market« took place for the seventh time in Manaus, Brazil. Since the beginning, the conference and exhibition has been organized by the Brazilian office of Fraunhofer ENAS supported by the Superintendency of Manaus Free Trade Zone, the Brazilian Ministry of Industry, Foreign Trade and Services and the Federal University of Amazonas. The motto of this year's conference with more than 200 participants and speakers was Industry 4.0.

Fraunhofer ENAS was Organizer/Co-Organizer of the following conferences and workshops:

ALD for Industry	Dresden, Germany	March 21, 2018
Smart Systems Integration Conference SSI 2018 (co-organizer)	Dresden, Germany	April 10–11, 2018
CMP/WET Workshop Spring Meeting	Amsterdam, NL	April 12–13, 2018
NIP/DF Printing for Fabrication 2018 (co-organizer)	Dresden, Germany	September 23–27, 2018
CMP/WET Workshop Fall Meeting	Berlin, Germany	October 25–26, 2018

Photo: Ines Escherich

EXHIBITIONS AND TRADE FAIRS

Science meets arts

In 2018, the art exhibition series »Science Meets Arts«, which was first launched in 2010, presented an exhibit called »RETROSPECTIVE« due to the 10th anniversary of Fraunhofer ENAS. The institute invited all 17 artists from previous exhibitions to present two of their artworks at the festive event and over the subsequent six months in the rooms of the institute. All regional artists followed our invitation so that the exhibition impressed many guests both at the festive event and at the exhibition in the institute building.

During the previously shown exhibition, Fraunhofer ENAS welcomed Anija Seedler, a graphic designer from Leipzig. She presented graphic works with the theme »MENAGERIE« to the employees of Fraunhofer ENAS and culture enthusiasts from Chemnitz. Anija Seedler's works include animal and human motives in bright and colorful pictures.

Fraunhofer ENAS is a member of the Fraunhofer network »Science, Art, Design«, which supported our exhibition at the 10th anniversary event. The network's goal is to support the interdisciplinary cooperation and examination of artistic methods for the discussion of complex social issues and to introduce research processes with new perspectives. Hence, the associated framework project invites Fraunhofer Institutes and Fraunhofer Research Institutions to an ideas competition with the goal of developing well-founded methods for successful collaborations between the various disciplines.

Chemnitz company run

For the seventh time, Fraunhofer ENAS and the Center for Microtechnologies of Chemnitz University of Technology participated in the Chemnitz company run. On September 5, 2018, 5 women and 15 men started in our running team. 8400 runners took part at the company run, our best male runner Jan Albrecht finished at position 288 and our best female starter Julia Hann at position 381. The four best male runners finished in 65th place, the best female team finished the run in place 66. The mixed team also finished 66th.

Congratulations! We are looking forward to the Chemnitz company run 2019.

Fraunhofer ENAS has presented its research results and prototypes at the following international trade shows and exhibitions in 2018:

European 3D Summit 2018	Dresden, Germany	January 22 – 24, 2018
embedded world 2018	Nuremberg, Germany	February 27 – March 1, 2018
LOPEC 2018	Munich, Germany	March 14 – 15, 2018
SEMICON China 2018	Shanghai, China	March, 14 – 16, 2018
Smart Systems Integration 2018	Dresden, Germany	April 11 – 12, 2018
HANNOVER MESSE 2018	Hanover, Germany	April 23 – 27, 2018
ILA – Berlin Air Show 2018	Berlin, Germany	April 25 – 29, 2018
mTEX+ / LiMA 2018	Chemnitz, Germany	May 29 – 30, 2018
SENSOR + TEST 2018	Nuremberg, Germany	June 26 – 28, 2018
SEMICON West 2018	San Francisco, USA	July 10 – 12, 2018
IMTS – International Manufacturing Technology Show 2018	Chicago, USA	September 10 – 15, 2018
MEMS Sensing & Network System 2018	Chiba, Japan	October 17 – 19, 2018
14. Chemnitzer Fachtagung Mikrosystemtechnik	Chemnitz, Germany	October 23 – 24, 2018
COMPAMED 2018	Duesseldorf, Germany	November 12 – 15, 2018
SEMICON Europa 2018	Munich, Germany	November 13 – 16, 2018
electronica 2018	Munich, Germany	November 13 – 16, 2018

MEMBERSHIPS

Memberships of Fraunhofer ENAS	
AGENT-3D e.V.	Dresden, Germany
ALD Lab Dresden	Dresden, Germany
biosaxony e.V	Dresden, Germany
Cool Silicon e.V.	Dresden, Germany
Dresden Fraunhofer Cluster Nanoanalysis	Dresden, Germany
Dresdner Gesprächskreis der Wirtschaft und Wissenschaft e.V.	Dresden, Germany
Eureka Cluster Metallurgy Europe	Ulm, Germany
European Center for Micro and Nanoreliability EUCEMAN	Berlin, Germany
European Platform on Smart Systems Integration EPoSS	Berlin, Germany
FED Fachverband für Design, Leiterplatten- & Elektronikfertigung	Berlin, Germany
Fraunhofer Alliance AutoMOBIL Production	Germany
Fraunhofer Alliance Nanotechnology	Germany
Fraunhofer Alliance Textile	Germany
Fraunhofer Group Microelectronics	Germany
Fraunhofer Cluster 3D Integration	Dresden and Chemnitz, Germany
Hzwo e.V.	Chemnitz, Germany
Industrieverein Sachsen 1828 e.V.	Chemnitz, Germany
InnoZent OWL e.V.	Paderborn, Germany
it's OWL – Intelligente Technische Systeme OstWestfalenLippe e.V.	Bielefeld, Germany
IVAM Microtechnology Network	Dortmund, Germany
MEMS Industry Group®	Pittsburgh, USA
Micromachine Center	Tokyo, Japan
Nano Technology Center of Competence »Ultrathin Functional Films«	Dresden, Germany
Organic Electronics Association OE-A	Frankfurt/Main, Germany
Organic Electronics Saxony e.V. OES	Dresden, Germany
Semiconductor Equipment and Materials International (SEMI)	San Jose, USA
Silicon Saxony e.V.	Dresden, Germany
VEMAS innovativ	Chemnitz, Germany
Partner in ZIM networks	
ZIM-Kooperationsnetzwerk »3D-Elektronik«	Darmstadt, Germany
ZIM-Kooperationsnetzwerk »Skalierung von Fügetechnologien in Produktionsprozessen für mikro- und makroskopische Anwendungen« (SCALE)	Chemnitz, Germany
ZIM Cooperation Network »Environmental Technology and Soil Reclamation« (UtBr)	Berlin, Germany

PUBLICATIONS AND PATENTS

Publications

In 2018, the scientists of Fraunhofer ENAS published their results in 137 book articles and conference proceedings as well as 4 book chapters.

You can find our published content:

1) Within the database Fraunhofer Publica which contains all publications and patents published by Fraunhofer Institutes:
http://publica.fraunhofer.de/starweb/pub09/newPub.htm
2) Moreover, they are listed on the website of our partner Center for Microtechnologies of Chemnitz University of Technology:
http://www.zfm.tu-chemnitz.de/publications/index.php.en

Electronically available documents can be downloaded via Fraunhofer Publica.

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Patents

In 2018, 9 patents from scientists of Fraunhofer ENAS have been published and/or granted. In summary, staff of Fraunhofer ENAS holds 180 patents in 56 patent families.

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